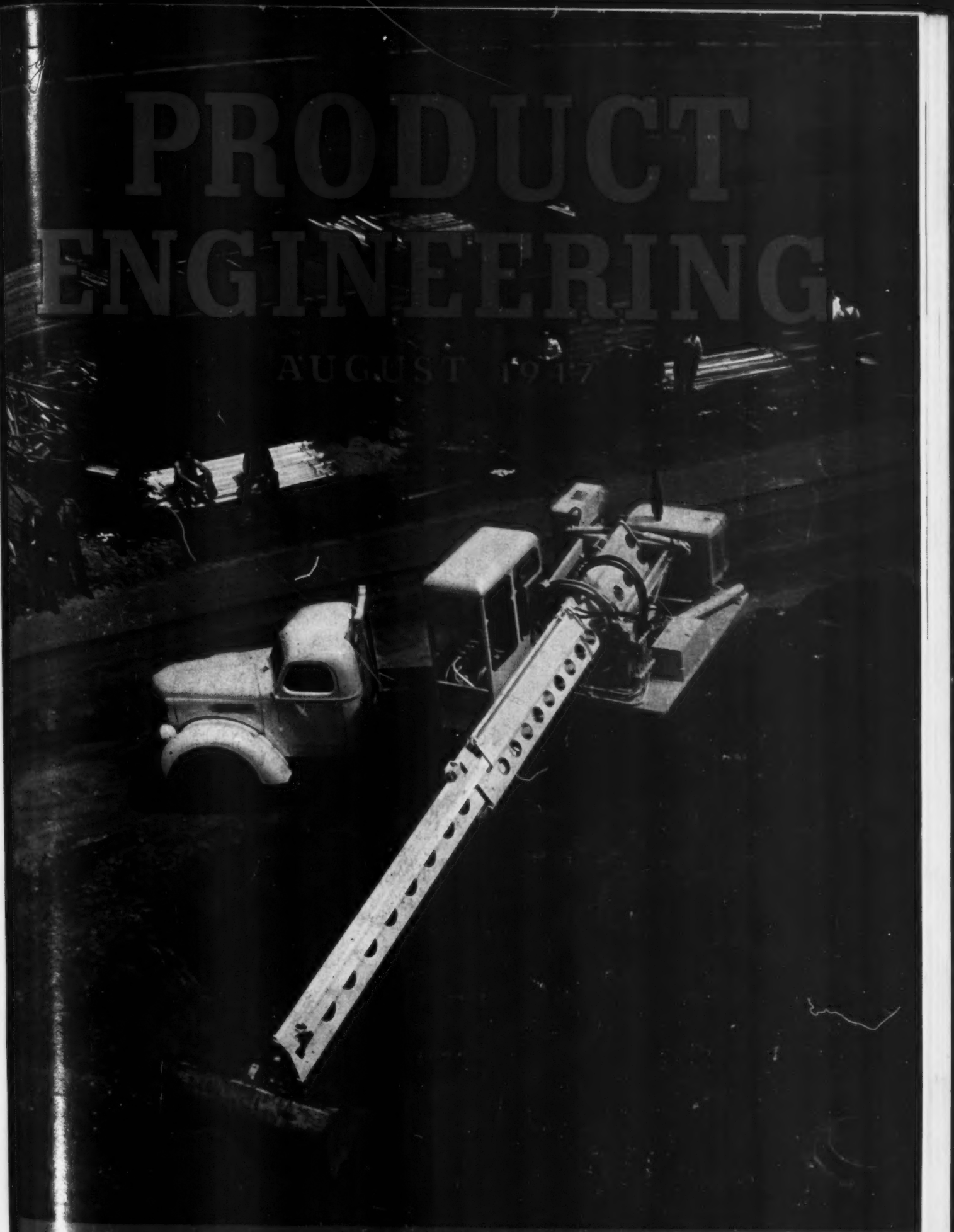
PRODUCT ENGINEERING

AUGUST 1947



IN THIS ISSUE—Hydraulic Earth Mover + Effect of High Pressure + Special Control Circuits + Iron Powder Parts + Designing Castings + New Uses for Shot Peening

McGRAW-HILL PUBLICATION

AN AGE-HARDENABLE

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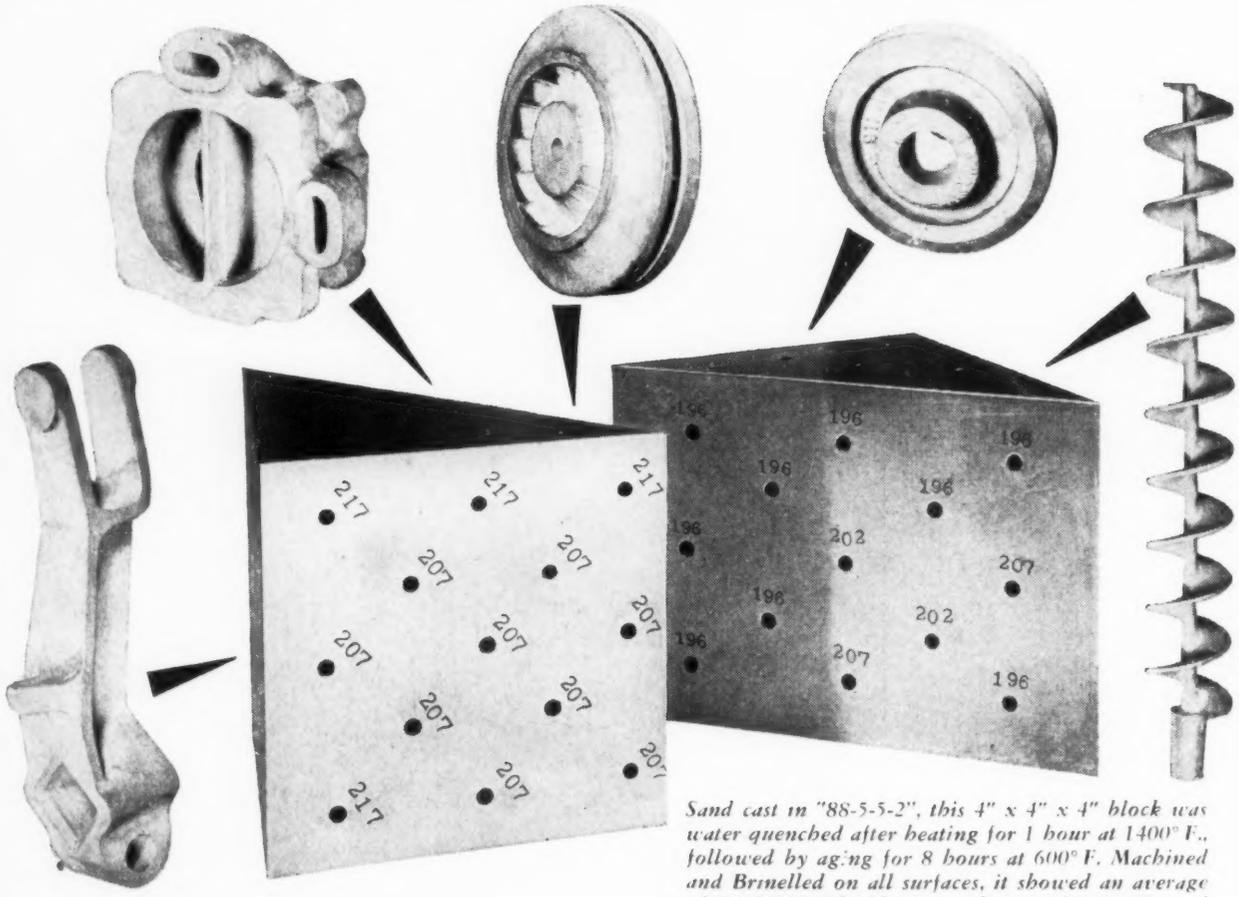

Sand cast in "88-5-5-2", this 4" x 4" x 4" block was water quenched after heating for 1 hour at 1400° F., followed by aging for 8 hours at 600° F. Machined and Brinelled on all surfaces, it showed an average of 209 BHN. The block was then cut diagonally, and both interior surfaces averaged 197 BHN.

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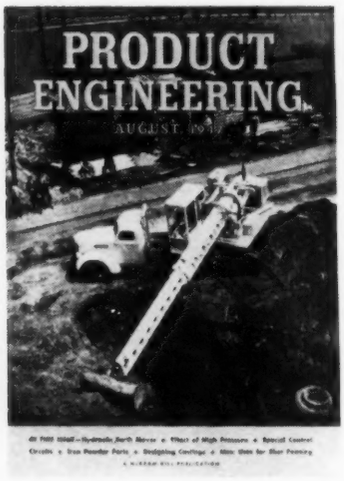

FRONT COVER

UNIQUE REACH and dexterity are provided by the hydraulically controlled 24-ft. telescoping boom of the Gradall. This unusual earth-moving machine, shown here in a back-filling operation on the campus of Case Institute of Technology, is discussed in the Product Design Section, page 90. Kodachrome courtesy of the builder, Warner & Swasey Company.

Effect of Pressure Cycling on Materials

Contemporary engineering, design and development have benefitted much from the findings of investigators in the field of high pressure research. Dr. T. C. Poulter, associate director at Armour Research Foundation, see page 81, discusses the changes in the physical properties that occur when materials are subjected to high pressures, and the equivalence of temperature and pressure cycling in relieving residual stresses in metal.

Steel Castings Design

In an article by Frank Kiper, plant superintendent, the Ohio Steel Foundry Company, beginning on page 86, the design of castings is discussed from the viewpoint of taking advantage of directional solidification for sound metal.

Parts Made From Iron Powders

Dr. Claus G. Goetzel, now of Columbia University, but formerly with American Electro Metal Corporation, in an article beginning on page 115, traces the development and improvement in parts made from iron powders.

Treatments for Metal Surfaces

Details of cleaning, chemical and electrochemical treatment, and painting of ferrous and nonferrous parts are covered in an article by E. F. Hickson and W. C. Porter of the National Bureau of Standards on page 128. Limitations and formulas of each solution mentioned are given.

Urea and Melamine Plastics

Urea and melamine plastics are tough, hard, water resistant and can be molded in an extremely wide range of colors. They are thermosetting and usually make excellent dimensionally stable industrial parts. On page 140, M. H. Bigelow and J. A. Murray, Plaskon Division, Libbey-Owens-Ford Glass Company, present properties and design factors of these versatile materials. In addition to molded products, applications covered include laminates, adhesives, coatings and insulation.

Special Control Circuits for Motors

Many industrial control requirements that cannot be met by standard motor controllers are easily provided by specially designed control circuits. On page 106, H. F. Littlejohn, Jr., Ward Leonard Electric Company, discusses typical application of special control circuits for motors including self-contained drives, programmed multiple units, multispeed drives, remote, and centralized control.

Centrifugal Governors

For certain horsepower motor applications electric governors are the best solution for speed control problems. On page 138, W. M. Yogerst, Bodine Electric Company, discusses preset and adjustable types of centrifugal governors. Typical constructions, basic control circuit, and motor operating characteristics are included.

Simple 8 to 1 Speed Control

An 8 to 1 speed range by field control of a d.c. motor is obtained by using two separate magnetic circuits and a two circuit armature winding. On page 166, R. W. Moore, motor engineer, Westinghouse Electric Corporation, explains how the system works and gives performance data.

Generation of Conic Sections

An article by R. T. Hinkle, associate professor of machine design, Cornell University, beginning on page 162, discusses the basic kinematics underlying the design of proposed machines for generating segments of the conics.

Shot Peening for Stress Corrosion Resistance

Shot peening has beneficial effects on metals other than those commonly associated with fatigue strength. An article by L. J. Wieschhaus, American Wheelabrator and Equipment Corp., beginning on page 122, discusses these other uses of the peening process.

Fluid Flow Between Parallel Plates

Many formulas and equations that correlate the factors in fluid flow are based on Newton's viscosity law. O. E. Teichmann of Armour Research Foundation, Illinois Institute of Technology, see page 146, shows how this simple law is fully adequate for solving many problems of fluid flow in engineering applications. Formulas are presented in tabular form for ready reference use.

SPECIAL SEPTEMBER ISSUE

Analysis of significant design features in some of the new machine tools to be exhibited at The Machine Tool Show, Sept. 17 to 26, Dodge-Chicago Plant, Chicago.

New constructions • New controls • New transmissions • New uses of materials

PRODUCT ENGINEERING Editorial

AUGUST, 1947

Solving The Problem of Machining Costs

"HIGHER WAGES AND LOWER PRICES" has been for many years the slogan of American industry. Great progress has been achieved by more efficient management, greater work productivity and by the use of manufacturing machines capable of faster production. The last is the essential ingredient that determines the limit to which costs can be reduced. Maintenance of prevailing wages rates and reduction of unit costs can be accomplished only through the use of better production equipment.

Radical and sweeping improvements in machine tools have not come in small changes in annual models. Whenever the economic picture called for lower manufacturing costs, machine tool builders always responded with amazing new models to meet the demand of industry for machines of greater productive capacity. They did it in 1935. They are doing it again. Next month, Sept. 17-26, at the Dodge-Chicago plant they will exhibit their new creations, which they offer to manufacturers for solving the present problem of higher wages and lower costs.

To achieve their goals, machine tool designers applied electricity, hydraulics, pneumatics, electronics, ingenious mechanical units and new materials. Results are astounding. Among the exhibits will be threading machines that produce twice as fast as the previous models, grinders that do the same job in one-sixth the time, planers that operate four times as fast, drilling machines that do the work of eight old style machines. By virtue of ingenious fixtures, feed mechanisms, push button controls and accessories, it requires less manual effort to operate the new models than the old ones, in spite of the many times greater production.

Machining costs, using these new tools, will take a steep drop. The new machine tools will make possible finishing specifications that are prohibitive if old machines are used. Designers will be able to develop quality products that can be made to sell in the buyers market that will soon be here.

At the Machine Tool Show, spread over 12 acres of exhibit space, there will be seen in operation machines demonstrating that precise dimensions and better surface finishes can be produced much more economically than formerly. Designers will see the answers to their most pressing question, "How can we design products to be produced at higher wages and sold at a lower price?"

G. F. Jordenholt

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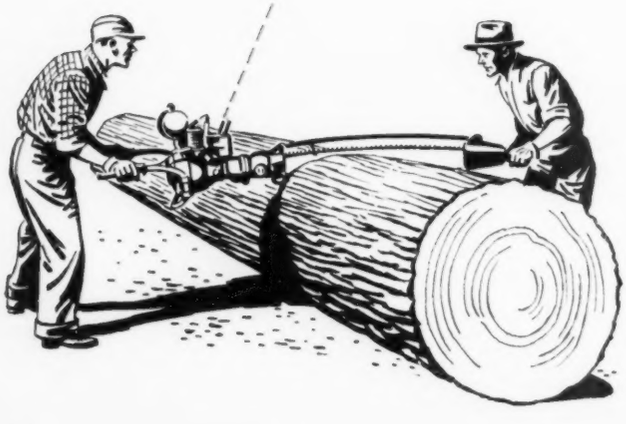

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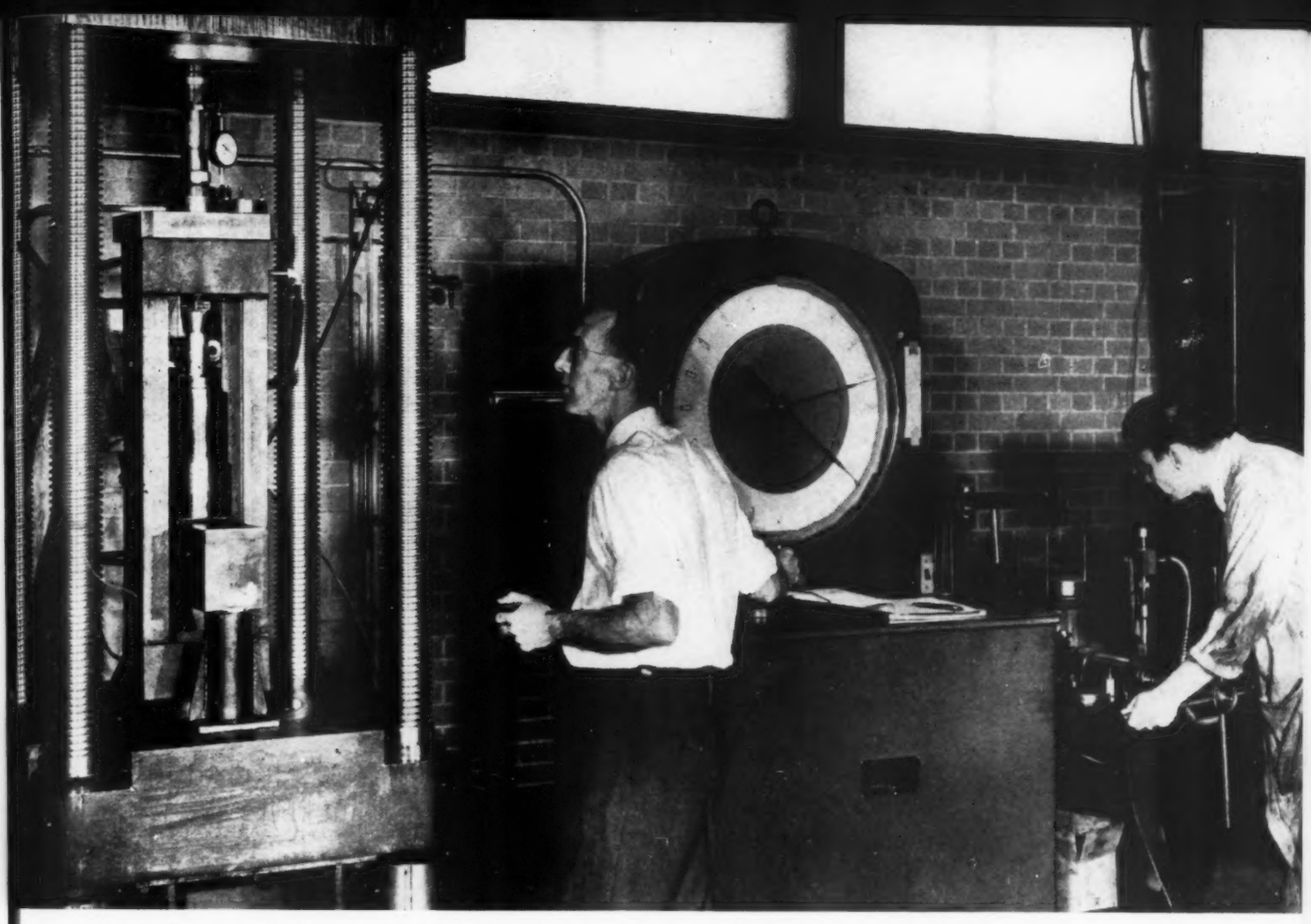


Fig. 1—Pressure cylinder mounted between hydraulic press platens for applying high fluid pressure on work specimens.

Effects of Pressure Cycling On Physical Properties of Materials

T. C. POULTER
Associate Director, Armour Research Foundation

MAXIMUM extreme pressures employed in research work are rising at such an increasing rate that even high pressure investigators are wondering what the future may lead to in this field. Up to the present time pressures, which if not controlled by man at least have been initiated by him, have exceeded one hundred-fifty million pounds per square inch. Such extreme pressures, obviously, can exist only momentarily.

If tensions in liquids are considered as negative pressures, then the limits of the range of pressures possible are greatly extended. The idea of tensions in fluid may be difficult to grasp. But if a long clean glass tube ¼ in. I.D., sealed at the upper end, is completely filled with gas-free water and then withdrawn carefully from fluid in a container, the top end of the tube can be raised without breaking the column of water to a height of 80 ft. above the surface of the water in the container. Thus the tension is about 22.5 lb. per sq. in. in the water near the top of the column.

Tensions of 600 lb. per sq. in. in water not perfectly air-free, and tensions of 90 lb. per sq. in. in water saturated with air, have been reported by H.N.V. Temperley and L. G. Chambers. (*Proc. Phys. Soc.*, London, 58, pages 420-436 July, 1946).

In an investigation of the effects of cavitation in hydraulic systems conducted at the Armour Research Foundation, it was found that it is not unreasonable to expect pressures in excess of 100,000 lb. per sq. in. to be developed at a point in the water as a cavity collapses. (See "The Mechanism of Cavitation Erosion," T. C. Poulter, *Journal of Applied Mechan-*

ics, Vol. 9, A-31-7, 1942). Such pressures are immediately dissipated in the form of a compression wave. When it is considered that a pressure of 0.2 lb. per sq. in. in a sound wave is painful to the ear, it is not surprising that the noise from cavitation in a hydraulic system can be very disturbing.

The major portion of the noise from propellers of a ship is a result of cavitation, a fact which was made use of extensively in both our submarine and anti-submarine warfare.

Not only is cavitation disturbing because of the noise produced, but it is the most destructive action confronting the hydraulic engineer. It is impossible to avoid cavitation completely by proper design, but there is no better way to reduce the disturbing and destructive effects of cavitation than by proper design. After the design has been carried as far as possible to prevent the occurrence of cavitation, then one can consider the selection of the proper material to resist the erosion.

In Fig. 2 is shown a disk cut from the low pressure side of the body of a pressure reducing valve. This valve was used in the water system of a large steam generating plant. The maximum water velocity through the valve exceeded 2,000 ft. per sec. Is it any wonder that the valve eroded badly and was extremely noisy?

Cavitation erosion occurs only on the low pressure side of the valve. It is not uncommon for serious erosion to occur in an elbow that is as much as ten feet away from the discharge side of a reducing valve. The centrifugal force of the water as it makes the turn in the elbow brings any remaining cavities to the inside of the turn, where they collect and collapse. It is also not uncommon for a pipe to be eroded badly just around and on the inside of the turn in an elbow down stream.

The most important points to be observed in avoiding cavitation from the standpoint of design can be illustrated by an analysis of a simple hydraulic mechanism—a hydraulic pressure reducing valve like that shown in Fig. 3. In the design of this valve, five important factors were not given proper attention:

1. The maximum velocity of the water is too high.

2. The rate of change of kinetic energy of the water as it goes through the valve is too great.

3. The velocity of the fluid at the point where the pressure has reached the desired minimum is too great.

4. The decrease in velocity is too abrupt.

5. The curvatures in the valve are too sharp.

Since these are the same factors that control the existence or nonexistence of cavitation and the resulting noise and erosion in most hydraulic mechanisms, it might be of some interest to consider what is to be desired on each of these points.

1. Wherever possible the velocity of the fluid should not exceed a few hundred feet per second.

2. The velocity changes effected in the fluid should be such as to change the kinetic energy of the fluid at as nearly a uniform rate as possible; that is, dv^3/dt should be as nearly constant as possible along the path of the fluid through the valve.

3. At the point where the pressure has been reduced to the desired minimum, the velocity of the fluid should be substantially equal to that of the

Fig. 2—Eroded disk cut from low pressure side of a pressure reducing valve.

Table I—Orders of Magnitude of Pressure in Fluids.

Lb. per sq. In.	Examples
− 15,000 to − 1,500	Tension in compression wave train in gas-free liquids
− 1,500 to − 150	Tension in compression wave or violent turbulence in liquids
− 150 to − 15	Column of water, compression wave
− 15 to 0	Column of water, compression waves
0 to 15	Vacuum to atmospheric range in laboratory techniques
15 to 150	Air pressure, water systems, fire hose, low pressure steam systems
150 to 1,500	Hydraulic and high pressure steam systems
1,500 to 15,000	Low order explosions, hydraulic systems
15,000 to 150,000	Cavitation erosion, high order explosions, hydraulic systems, contact pressures on jewel bearings in electrical instruments
150,000 to 1,500,000	Extreme pressure work
1,500,000 to 15,000,000	Shaped charge
15,000,000 to 150,000,000	Atomic bomb explosions. Meteors in collision

fluid in the pipe at the point where the fluid leaves the valve.

4. The rate of decrease in velocity must never exceed a value such that the change in velocity head exceeds the pressure head.

5. Any curvature in the fluid path must be of sufficiently great radius that the resulting centrifugal force acting on the fluid at any point does not exceed the fluid pressure at that point, that is, where:

M = mass of fluid
v = velocity of fluid
R = radius of curvature of fluid path
P = fluid pressure
a = cross-sectional area
$Mv^2/Ra \leq P$

Then where

s = distance along path of flow
K = a constant for the particular fluid at a given temperature. (For water at 100 deg. C., $K = 0.0000355$)
W = clearance space for the fluid, or distance between the two surfaces between which the fluid is passing
v = velocity of the fluid at the point in question

the pressure drop along the path of the fluid when these five conditions are met can be expressed by

$$\frac{dP}{ds} = K\,W^{-1.3}v^{1.7}$$

The valve shown in Fig. 4 (Patent No. 2,342,890, Feb. 29, 1944) is an attempt to meet the five requirements of correct design.

In hydraulic systems, aside from any of the accompanying destructive erosion effects, cavitation is perhaps the most troublesome phenomenon encountered. Cavitation also is an important factor in decreasing volumetric efficiency at high flow rates.

When a compression wave is transmitted through water, the average pressure throughout the wave will be the fluid pressure of the water at that point. On the basis of the energy that can be transmitted through gas-free water, in the form of a compression wave of sufficiently high frequency and amplitude, it can be shown that tensions of as much as 12,000 lb. per sq. in. can be developed in water.

Measuring both ways from a perfect vacuum, Table I gives in terms of pounds per square inch orders of magnitude of pressures that can exist in fluids and also examples of physical phenomena that would produce such pressures.

A striking correlation exists between the changes produced in physical properties of materials by a decrease in temperature and an increase in pressure. Not only are these changes in properties qualitative in the same direction as indicated in Table II, but frequently a quantitative relation exists in the magnitude of these effects. It is the opinion of the author that many more such quantitative relations exist that have not yet been recognized.

In studies on the effect of pressure on the viscosity of oils, it has been found that the values obtained are roughly a function of density, regardless of whether that density was obtained by adjusting the temperature or the pressure. This is also true in general of electrical and thermal conductivity, magnetic permeability, dielectric constant, and even hardness. A number of organic liquids, particularly petroleum oil products, when subjected to enormous pressures acquire hardnesses ranging from that of lead to that of copper; some organic compounds acquire hardnesses equal to that of steel.

For years man has attempted to reach a temperature of absolute zero, and in doing so he has discovered many interesting phenomena, such as superconductivity and numerous photosensitive processes.

Theoretically it appears impossible to reach a temperature below absolute zero, but investigators often wonder what might lie beyond that theoretical low temperature limit.

In pressure lies a chance to take a peek behind that limit, since so many physical properties of matter are a function of density and by means of pressure the densities of many mate-

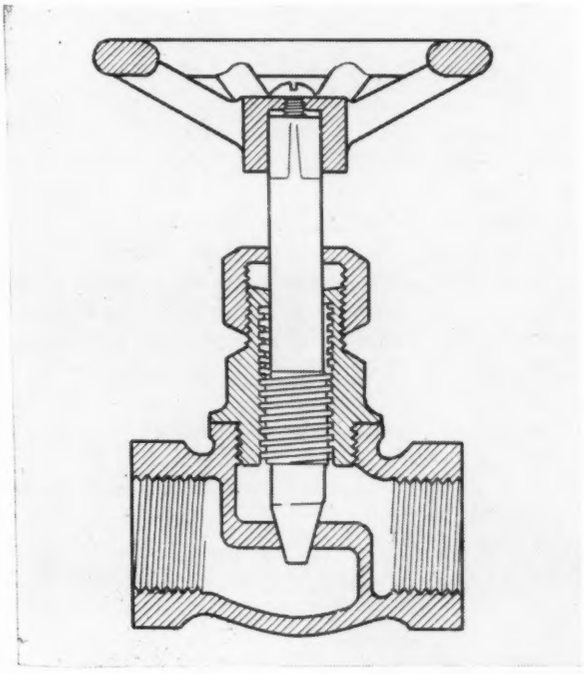


Fig. 3—Sectional view of a typical hydraulic pressure reducing valve. In this valve, with parts proportioned as shown, the rate of change of kinetic energy of the water as it goes through the valve is too great.

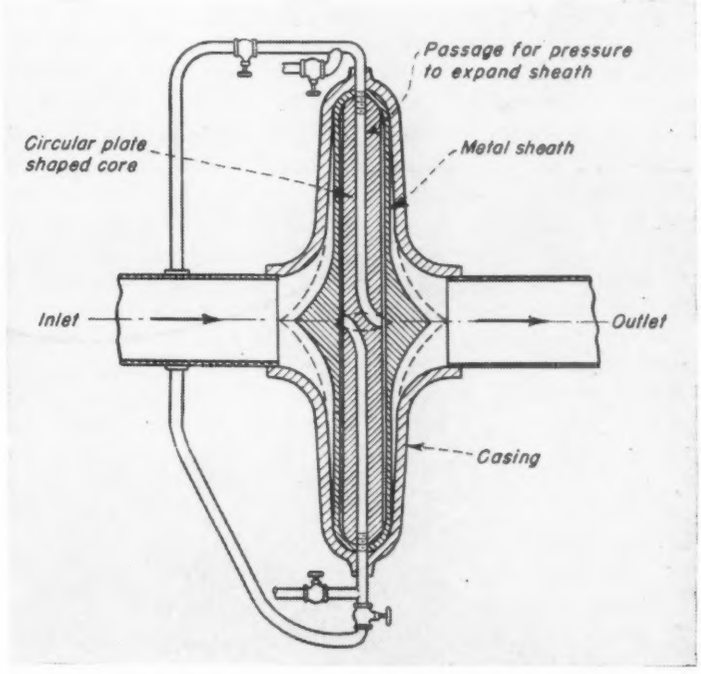


Fig. 4—Low-velocity pressure-reducing valve in which some of the pressure head is dissipated by spreading a confined stream of fluid in a sheet between the metal sheath and casing, after which the stream is restored to a compact cross-sectional form.

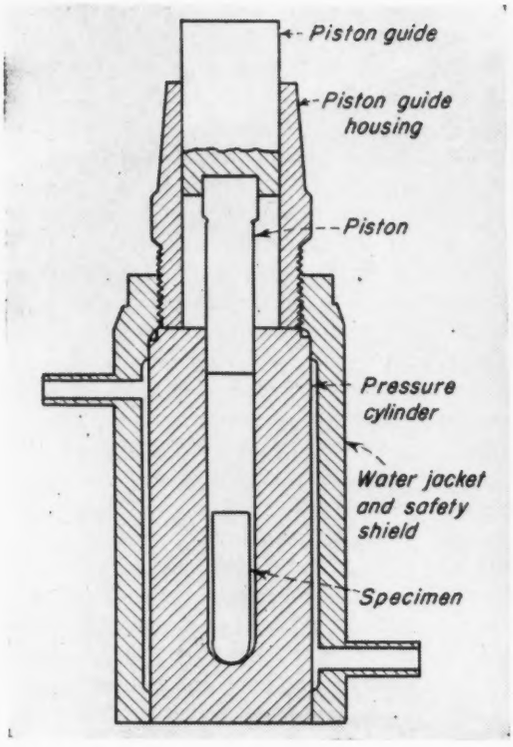


Fig. 5—Cylinder in which specimens were placed to determine the effect of pressure cycling.

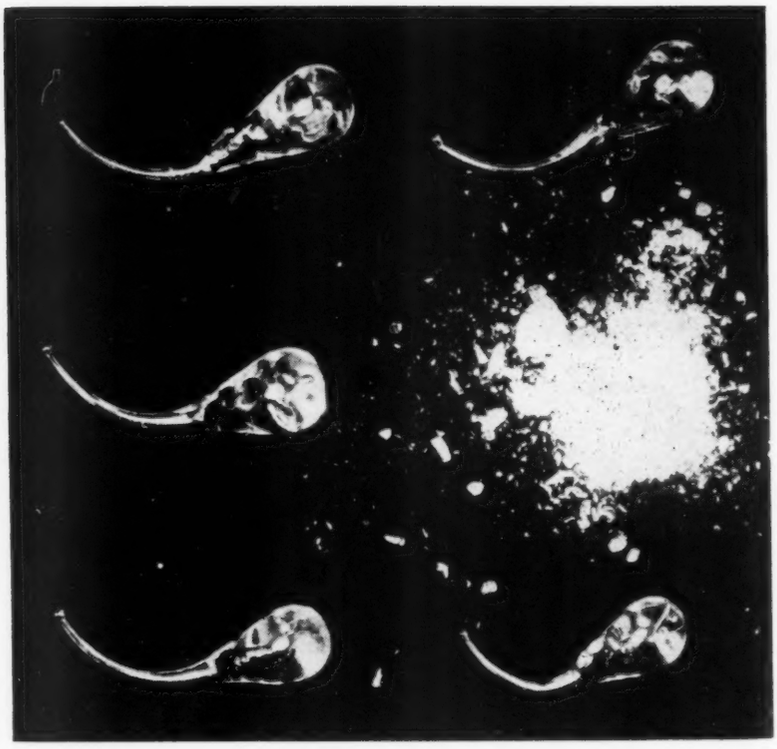


Fig. 6—Prince Rupert drops. When the drop is scratched or the tail broken, internal strains are released and the drop bursts into fragments.

rials can be carried beyond that obtainable by lowering the temperature to absolute zero.

It would be extremely interesting to make a study to see if superconductivity conditions can be reached by means of the extreme pressures now obtainable instead of low temperatures. Perhaps some materials having a high electrical resistivity could be made to acquire a good electrical conductivity. Such a study would throw some additional light upon the mechanism of the conduction of an electric current in solids. In connection with studies of the "Effect of Pressure Upon the E.M.F. of the Weston Standard Cell" (Thos. C. Poulter and C. Ritchey, *Physical Review*, pages 816-820, Vol. 39 No. 5, March 1, 1932), conductivity measurements were made on the oil used to surround the cell. Although the effects were negligible for the measurements being made, a slight increase in conductivity was observed at twelve thousand atmospheres.

Another important way in which temperature and pressure effects have been found to be equivalent is in the relief of residual stresses in metal. An old process, still in common use, for relieving stresses in metals accomplishes that result only by maintaining the metal at an elevated temperature for a period of time. Later it was found that if the temperature was cycled a few times residual stresses could be relieved more completely than by prolonged heating.

Some good experimenter concluded that if the process of changing the temperature was helpful, then why not cover a wide temperature range by using a low minimum value. Cycles between 100 deg. C. and dry ice temperature, therefore, have been standard for several years for stress relieving and accelerated aging of metal parts where maintenance of precise dimensions over a period of years is important. This process is used in the manufacture of lapped fits and precision gage blocks.

Such temperature cycles were found to be even more effective on many of the aluminum-copper alloys that are commonly used for making precision machined parts for military computing mechanisms, particularly if these parts are machined from rolled plate.

It is not uncommon for a strip one inch wide by one foot long, cut from a rolled plate of Dural (17ST, 24ST) one-fourth to one-half inch thick, to warp as much as a quarter of an inch out of straight upon having a very thin layer of metal machined from one surface. This tendency disappears almost completely after two temperature cycles between 100 deg. C. and the temperature of dry ice.

It has also been found that the transmission of a compression wave of large amplitude through steel castings will often accomplish considerable stress relieving. Some foundries have adapted a procedure of vibrating castings or subjecting them to severe shocks to accomplish at least a partial stress relieving.

Being more than usually pressure conscious, it occurred to the research personnel at Armour Research Foundation that in the cases discussed the important thing in a temperature stress relieving cycle is perhaps not change in temperature but the accompanying change in volume.

Some experiments designed to determine the effectiveness of a pressure cycle in relieving stresses were therefore undertaken. To use large pressures, it was necessary to select small specimens that could be placed in the pressure cylinders, Fig. 5. It was also desirable that the specimens exhibit large residual stresses, the presence of which could be easily detected.

Two different types of specimens

Table II—Effect of Temperature and Pressure Upon Physical Properties of Matter

Legend: ↑ Increase ↓ Decrease

Property	Decrease in Temperature	Increase in Pressure
Density	↑	↑
Index of refraction	↑	↑
Electrical conductivity	↑	↑
Thermal conductivity	↑	↑
Magnetic permeability	↑	↑
Dielectric constant	↑	↑
Optical rotation	↑	↑
Physical strength	↑	↑
Elongation	↑	↑
Hardness	↑	↑
Viscosity	↑	↑
Specific heat	↕	↕
Volume	↓	↓

were selected, the Prince Rupert drop of glass and a strip of 24ST. The Prince Rupert drop, Fig. 6, has a long tail and is made by dropping melted glass into water. The drop is remarkable for the property of bursting into fragments when the surface is scratched or the tail broken. The Prince Rupert drop was selected as exhibiting the maximum in stress that could be thought of and also because glass would be a difficult material in which to produce plastic flow at room temperature. The 24ST aluminum alloy was selected because the effects of the temperature cycle were known.

Either specimen could easily be tested for the effectiveness of the process: The Prince Rupert drop by observing any decrease in its tendency to shatter when the tip was broken off, and the 24ST strip by machining a thin layer off one surface and comparing the resulting curvature with a control specimen cut from the same sheet.

A considerable number of Prince Rupert drops were made, and several of them cycled twenty times between atmospheric and 70,000 lb. per sq. in. pressure. While it was still possible to obtain shattering in some of the pressure-cycled specimens, their tendency to shatter was very appreciably decreased.

This method proved useful in relieving residual stresses in small glass capsules used in certain military applications. The procedure that was adopted produced a pressure in the glass in excess of 100,000 lb. per sq. in. and served the dual purpose of eliminating those specimens having thin sections and of relieving the stress in the remainder. A production of as many as eighty thousand capsules a day was treated by this method with no service failures resulting from residual stresses in the glass. With this method of stress relieving a complete pressure cycle can often be completed in less than a second, so that where a few hundred or thousand cycles are needed, the time required for cycling is not necessarily excessive.

The test and control strip specimens were ½ in. wide by 6 in. long, cut from a ⅛ in. thick sheet of 24 ST, and were marked to identify one side of the original sheet. The test specimens were cycled twenty times at 140,000 lb. per sq. in. When 0.02 in. was machined from the same side of the test specimens that had been cycled and of the control specimens, the test specimens showed less warping than the control specimens. Fig. 7 shows typical curvature of the specimens.

Two similar strip specimens were then shot-blasted on both sides so that they were straight. One specimen was then cycled ten times to 140,000 lb. per sq. in. After machining 0.02 in. from one surface of both the control and the test specimens, the curvature of the specimen that had been pressure cycled was thirty percent smaller.

Many more examples could be cited to illustrate the effects of pressure cycling on the physical properties of matter. Undoubtedly, con-

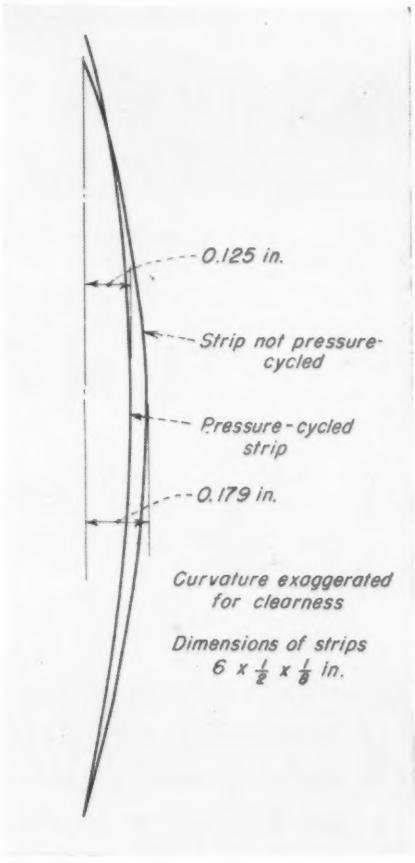


Fig. 7—Curvature taken by aluminum alloy strip specimens after machining 0.02 in. from one surface of each.

temporary high pressure investigations will result in advances in numerous fields of engineering design. The progress that has been made, during the past eighty years especially, is evidenced by the large number of investigators who have become engaged in high pressure work and by the hundreds of articles that have been published. At the present time a wealth of high pressure data are available in the literature.

Centrifugal pump casing of cast steel for high-pressure, high-temperature service.

Steel Casting Design Details Affect Quality of Product

FRANK KIPER
The Ohio Steel Foundry Company

Directional solidification and the control of it in the production of sound steel castings. Temperature gradient is divided into a transverse component or approximate temperature gradient and a longitudinal component, called the section gradient. The use of the components by the designer to improve the quality of steel casting is explained and illustrated.

METAL is distributed in designing cast parts to join one member to another; to get rigid members; to obtain cross sections that will resist static, impact or fatigue loads; to exhibit a well-proportional appearance; to get a sound cast structure. These are not all the reasons of course; nor does the designer always give consideration to all of these five, particularly the last.

Steel castings frequently are the basic parts around which other parts are designed and to which the other parts are affixed. In this respect the casting is the part that joins the members. In the major parts of pressure vessels, compressors, valve bodies, testing machines, turbines and other machinery, strength or resistance to applied loads is an essential requirement of the metal. Many times a steel casting is specified by the designer largely because of the strength properties of steel in comparison with those of other metals. If so, that designer will be doubly interested in designing the part to get a sound cast structure, which means designing so that the distribution of the metal in the part will solidify with maximum strength during the cooling and setting process.

Solidification in a casting starts at the metal-against-mold interface and progresses toward the hottest metal. As the layer against the mold changes from the liquid to the solid phase, the steel shrinks. So long as liquid metal is available at the hotest spot and if it is not prevented from flowing counter to the progress of solidification, liquid metal will flow in to keep the casting filled and shrinkage will not cause defects in the casting, such as voids, pipes and outer weakness.

Temperatures of the solidifying

metal can be visualized in two ways: First, all the spots of equal temperature within the cooling metal might be grouped together. They would represent a series of shells, one inside the other, with that shell against the mold being the coldest. A section through the casting could be shown as a series of lines of equal temperature or isotherms, Fig. 1. Second, the instantaneous freezing front through the metal along which the temperature increases, that is the temperature gradient, can be considered.

The temperature gradient cuts across the isotherms, going from one to the next in the direction of the hottest metal. It establishes therefore a direction of solidification because the coldest metal lies along it in the direction opposite to that of hottest metal. In cross section, Fig. 1(A), the temperature gradient is a curve, which indicates that in the casting where three dimensions are involved the temperature gradient would follow a warped surface of some kind.

Although much has been written about controlling directional solidification, little has been done to give the designer simple means of applying its basic principles in design calculations. The author uses this temperature gradient by dividing it into two parts: (1) The temperature change or gradient from one isotherm to another within a transverse plane, beginning at the mold surface and moving inward, Fig. 2(*A*). (2) A section gradient, or change of volumes from one section to the next, the sections being parallel to a plane of temperature change.

The tapered section illustrates this section gradient. The idea is to make the sections successively larger toward the well of hottest metal. Fig. 2(*B*) illustrates what happens when the section gradient decreases toward the liquid supply source: the flow channel gets choaked by solidifying metal and shrinkage causes a socalled pipe or defect in the casting. In the first illustration the section gradient aids temperature change, the two combining in an additive manner. This principle is known as "controlled directional solidification".

Casting design will promote directional solidification if the thin sections are proportioned so as to increase with nearness to heavy sections. The foundry-man always gates the molten metal into the heavy sections. Gates and risers are his responsibility, not the designer's. The foundryman also applies partial reversal of the mold, top pouring, heading, chilling and padding in controlling directional solidification, but these would come to the attention of the designer only for unusual or complex castings, and then most likely in a conference of designers and foundrymen about a specific design. Tapered sections, on the other hand, are everyday, good design practice.

To illustrate the application of the taper-section principle, suppose the

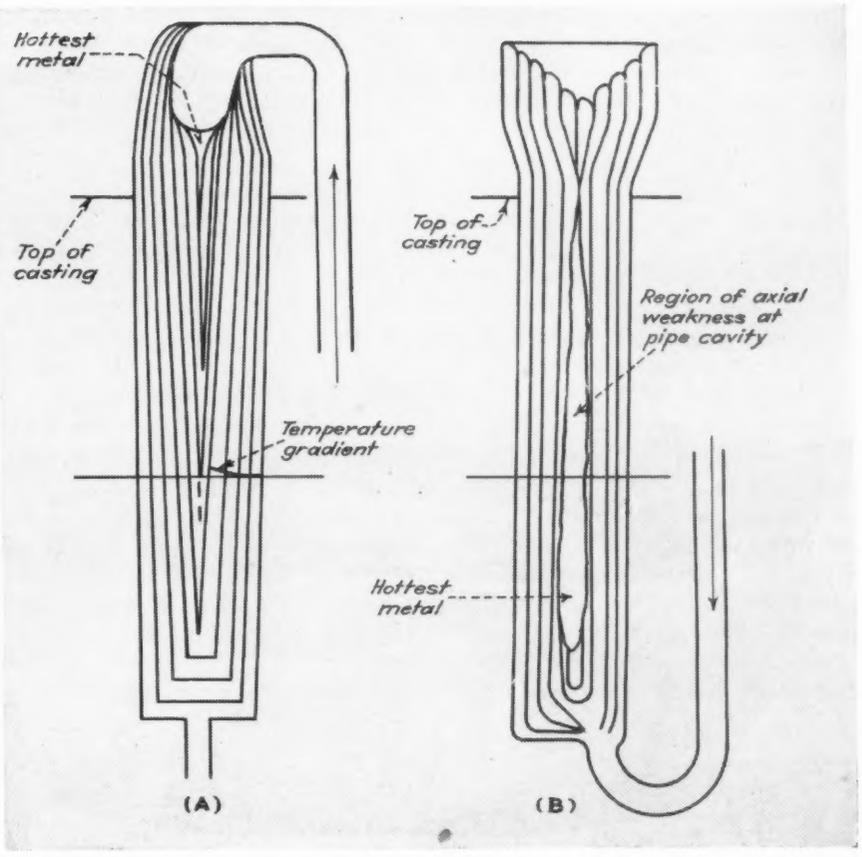


Fig. 1—(A) Hottest metal from top pouring flows into shrinkage space to produce sound casting. (B) Defect caused by insufficient molten metal to offset shrinkage.

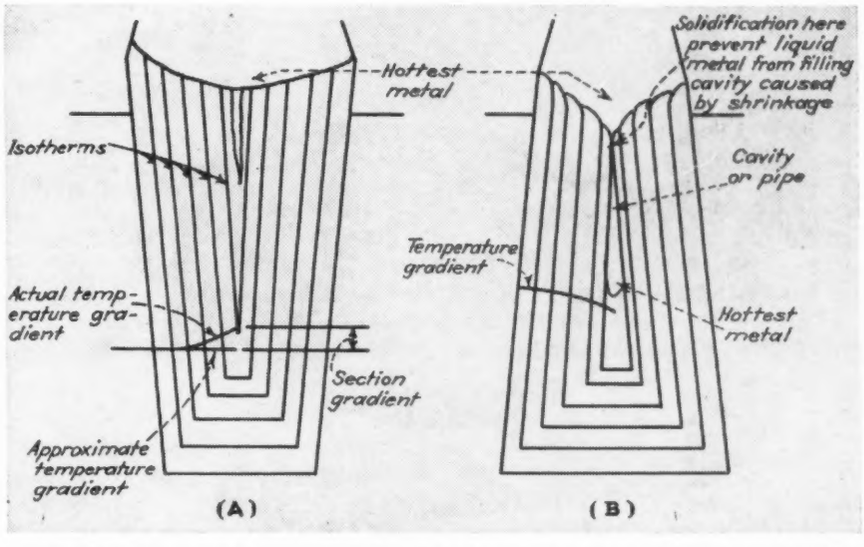


Fig. 2—(A) For practical purposes the actual temperature gradient is equivalent to an approximate temperature gradient plus a section gradient; (B) Condition where the section and temperature gradients do not unite to make sound metal.

two diagrams of Fig. 3(*A*) and (*B*) are alternate ways in which a cylindrical part might be cast. Obviously (*A*) more nearly has the geometry of a tapered section. Fig. 3(*C*) is a section through a web-type inertia wheel. The rim is the heavy section. The web is tapered toward the rim; the generous fillet at the hub is also an effective taper section. Compared with a wheel of equal weight having a web of uniform thickness this design distributes more metal toward the rim where it is wanted. In a disk-type wheel, say a wheel holding the blades of a steam turbine, the heavy section is the hub. The tapered section then would be toward the hub. Beads at the edges or around windows in castings can generally be added without regard to the direction of solidification. Normally such beads do not have an over-all thickness that exceeds twice the section thickness. Under these limitations both the area in contact with the mold and the volume are roughly double; hence solidification with or without the bead are practically simultaneous.

Different masses of metal at unequal distances from the heavy section also can be designed to give a tapering section effect. Consider the frame of Fig. 4. Here the heavy section is at the top. The leg sections are tapered to aid directional solidification. So are the cross-tie sections, but the one the farther from the heavy section has the thinner section and consequently the lesser mass.

Tapers of five degree, which is less than the draft normally allowed on forgings, are helpful toward directional solidification. Ten or fifteen degrees is better. The fillets customarily used for grey iron are hardly suitable for the junctions of the tapered sections. Fig. 5 shows some sections and contains a table of suitable radii. These values are not expressly intended to define limiting dimensions.

Cores are always a bugaboo to both the designer and the foundryman. Nevertheless they should be used wherever necessary for holes and to reduce the mass of sections. In designing to aid directional solidification, they can be considered and treated just as additional mold surface insofar as temperature gradient is concerned except when they are comparatively small with respect to the surrounding initial section so as to become hot during casting. When cores are introduced to reduce mass, then the position of the mass relative to other masses and to the heavy section may be worth considering in determining the section gradient.

As a further example of design to

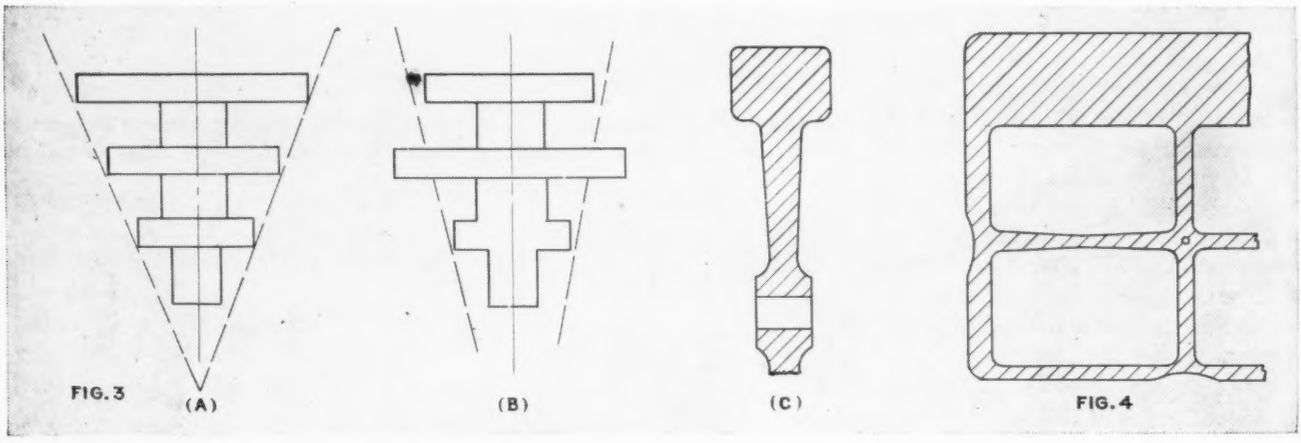
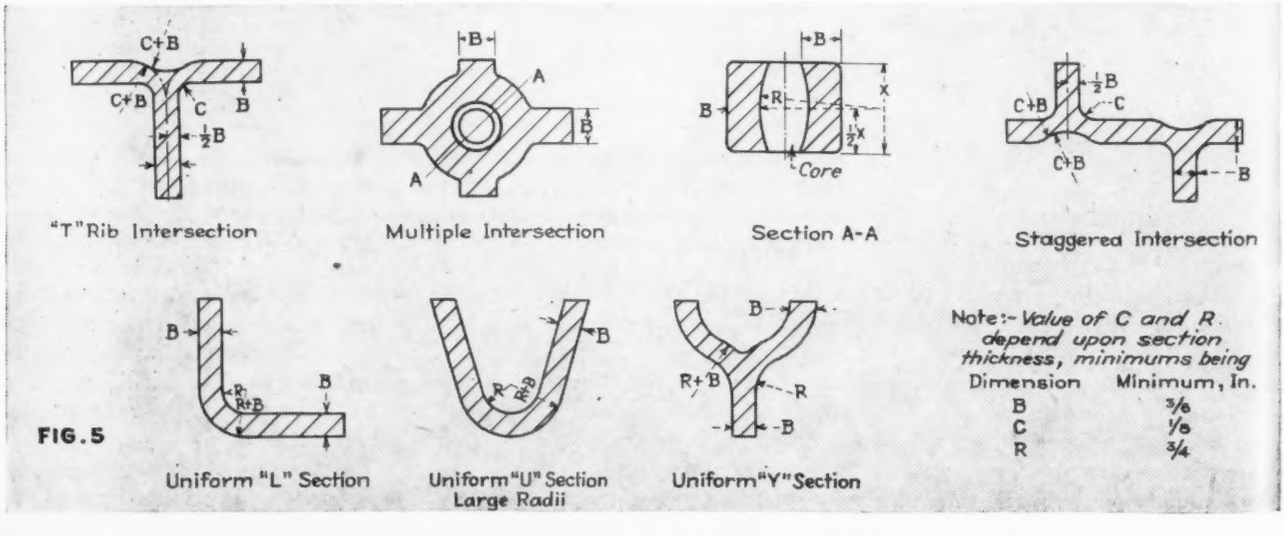


Fig. 3—(A) Sections with volumes that conform approximately to the taper pattern; (B) Sections that upset taper pattern; (C) Inertia wheel with taper web. Fig. 4—Frame construction in which sections farthest from the heavy section are made thinner than the nearer sections. Fig. 5—Fillets for taper sections of various thicknesses.



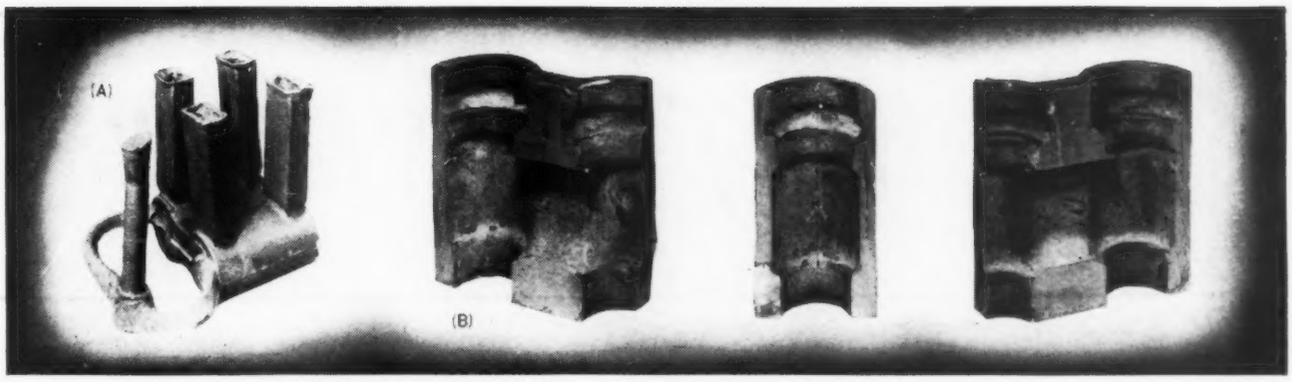


Fig. 6—Original design with risers to each heavy section that produced steel casting that was not altogether satisfactory.

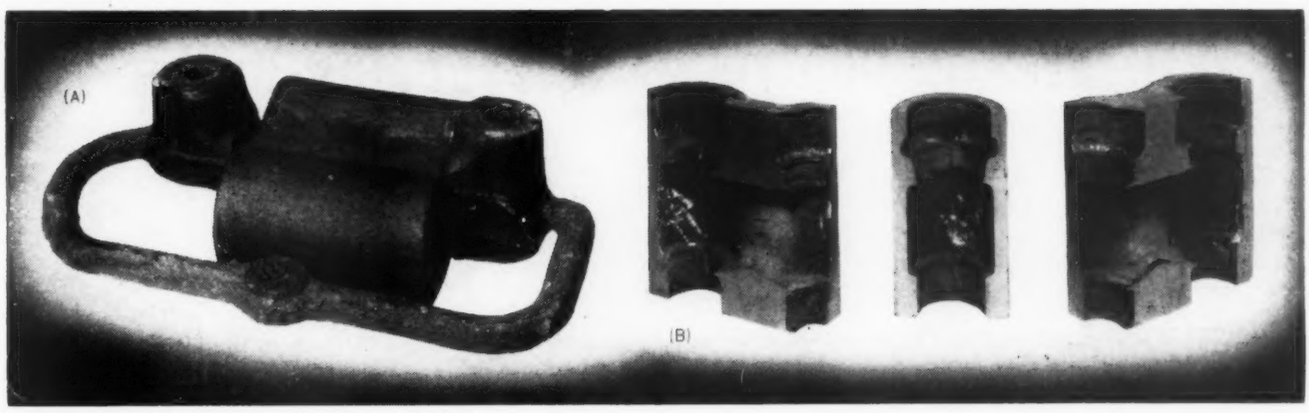


Fig. 7—Same design with foundry technique to take advantage of transverse temperature gradient gave better casting.

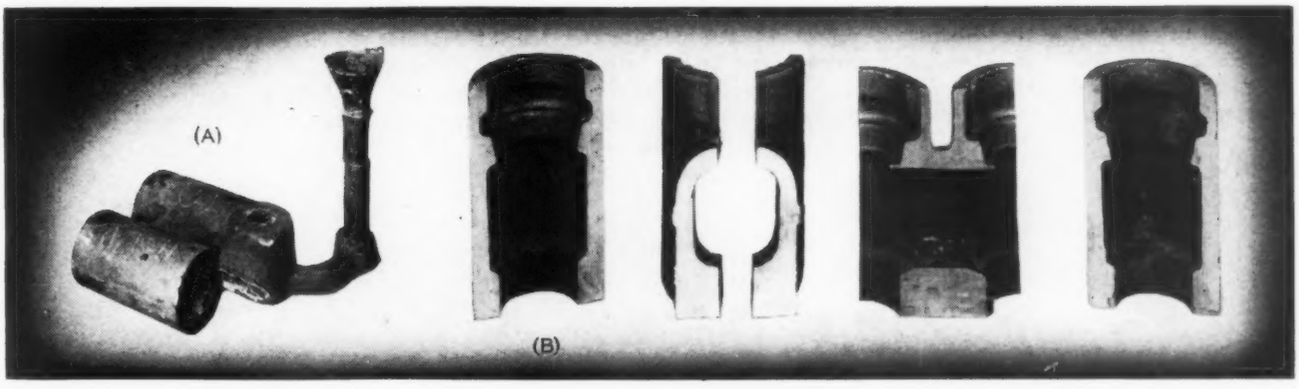


Fig. 8—Redesign to take advantage of both temperature and section gradients produced a casting of best quality.

provide directional solidification consider Figs. 6, 7 and 8. Fig. 6 represents the initial design and an attempt of the foundry to produce a sound casting. In spite of the four large risers and the excess of feeder metal, defects are in evidence, Fig. 6(*B*). A great volume of feeder metal alone is not always an assurance of a sound casting.

A sound casting was obtained, Fig. 7(*B*), when the hot metal was gated into the casting by way of the two heads, which are adjacent to the heavy sections of the castings. The design is the same as Fig. 6 but the difference in feeding took advantage of the temperature gradients. Further, less metal is wasted since the volume of the feeder metal is reduced; fewer risers are required, which reduces labor cost.

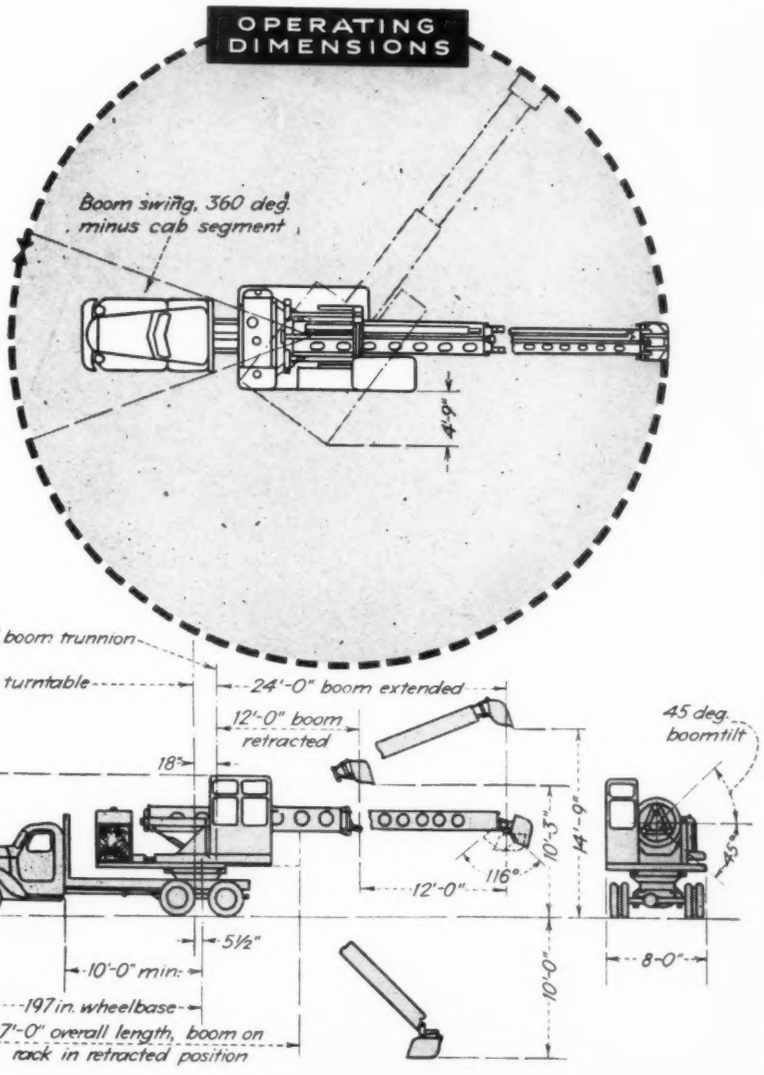
Still further improvement was achieved when both temperature gradients and section gradients were put to work. By a change in design, without altering in any way the use of the part, the heavy section at one end was eliminated and the walls were tapered about 10 degrees. The metal was gated into the casting through the head that was adjacent to the heavy section, Fig. 8. The opposite heavy section was increased in area for faster cooling, which plus some outside chilling, produces a sound casting.

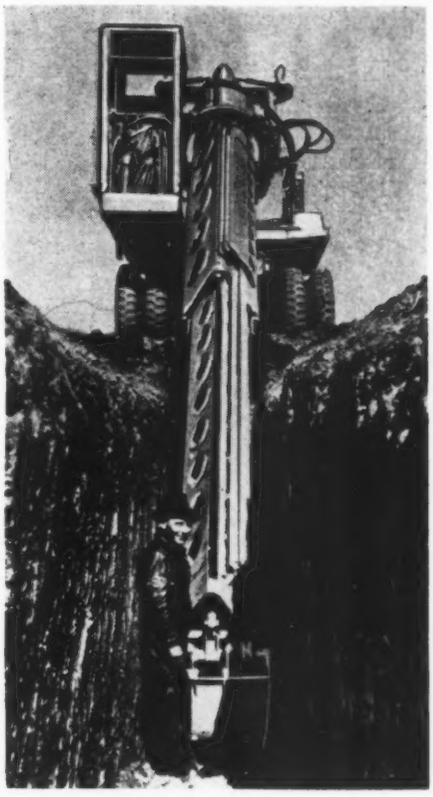
The last example illustrates the development method of arriving at a satisfactory design along with the application of the directional solidification upon which the redesign was based. How much more gratifying would the design have been if the development had been unnecessary.

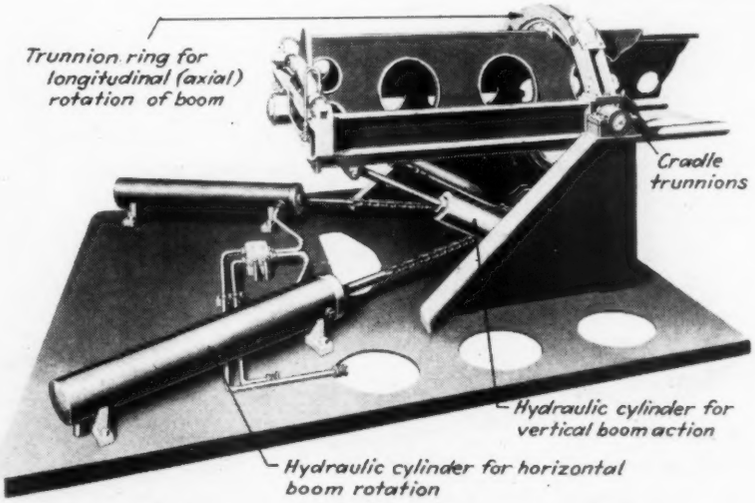
PRODUCT DESIGNS

Hydraulic Control of Telescoping Boom Makes Versatile Earth Mover

SENSITIVE, all-hydraulic control of interchangeable tools and the telescoping boom on which they are mounted enables the Gradall to perform a wide variety of earth moving jobs. The multi-purpose earth mover, invented by Ray Ferwerda and manufactured by Warner & Swasey Co., Cleveland, can be likened to a giant mobile arm that can reach up and down, around or over obstructions to actuate a variety of tools. The precision of movement adapts the machine to some work heretofore performed by hand labor. An all-welded triangular boom, each section composed of three tubular members welded to steel plates, can be extended between 12 and 24 ft. from the pivot point. Boom and tool also can be raised, rotated and tilted, as shown in the sketch. Horizontal rotation of the boom platform is possible in either direction except for that part of the circle obstructed by the truck cab. Working action is one of pulling rather than pushing. Digging, trenching, ditch cleaning, snow removal and cleanup buckets and blades are among the attachments shown in the action pictures. The boom unit is mounted on a truck chassis for mobility. Weight of Gradall unit is 16,000 lb., excluding tools. Any of the tools can be interchanged in less than 15 minutes.

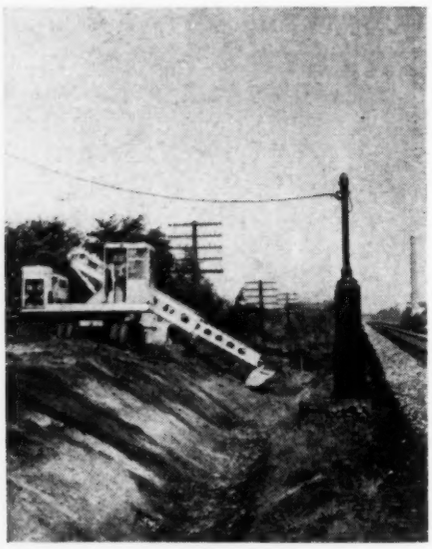


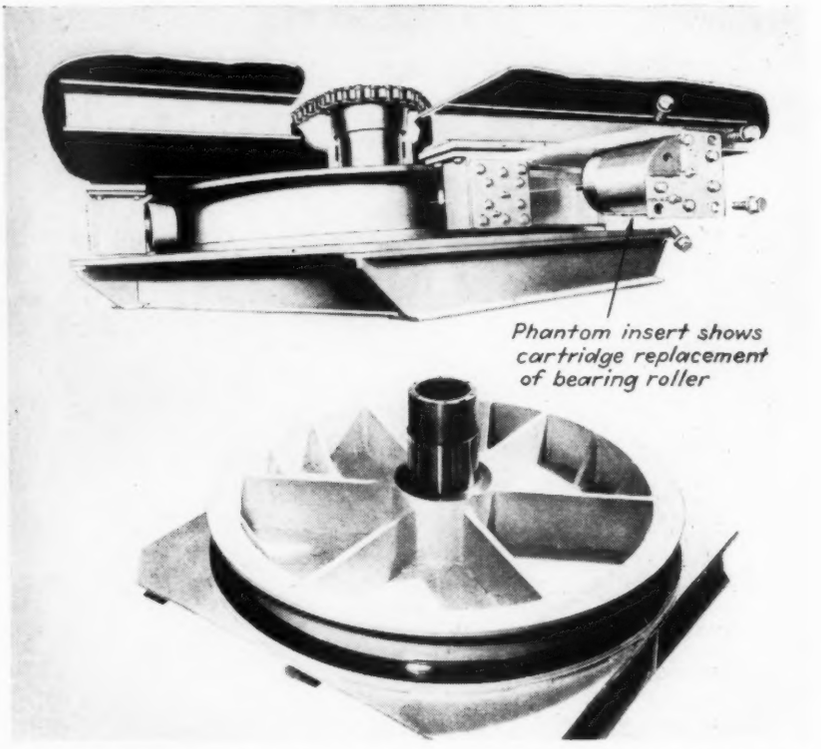



Trunnion ring for longitudinal (axial) rotation of boom
Cradle trunnions
Hydraulic cylinder for vertical boom action
Hydraulic cylinder for horizontal boom rotation

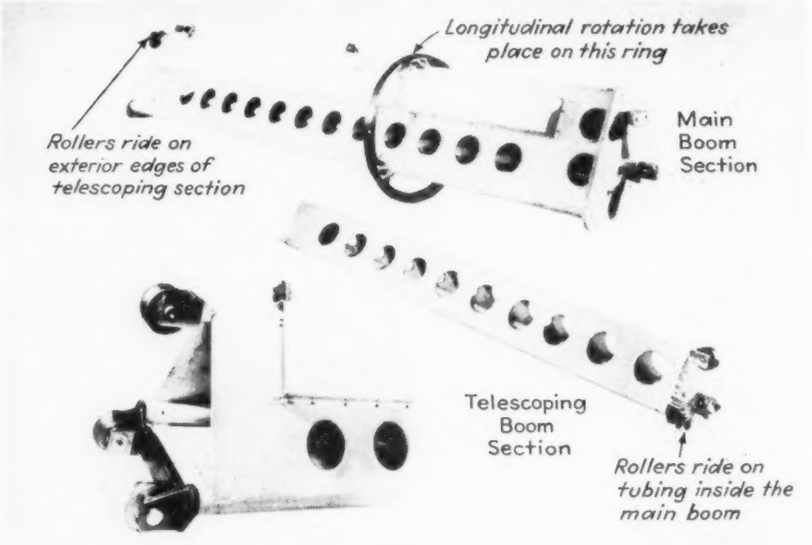
A welded steel bed forms the rotating platform that carries boom, boom cradle, engine, pumps and the hydraulic cylinders that control boom movement. Rotation of the platform is accomplished by two single acting hydraulic cylinders pulling a 2 in. pitch chain about a sprocket rigidly fastened to the large center pin. Two displacement type cylinders rotate the boom on its axis, two double acting cylinders raise and lower the boom, one double acting type extends it. A single cylinder actuates the tool.

(*Continued on next page*)

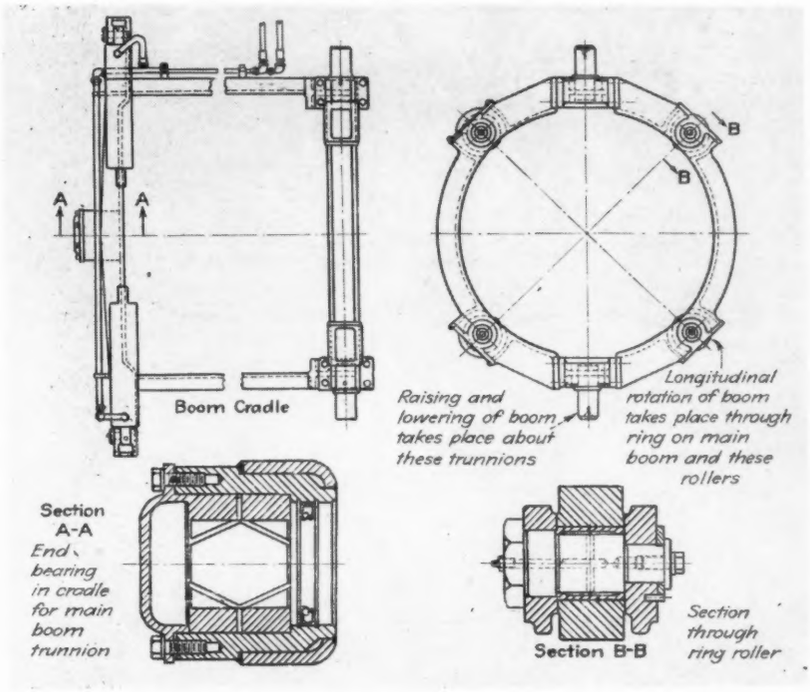




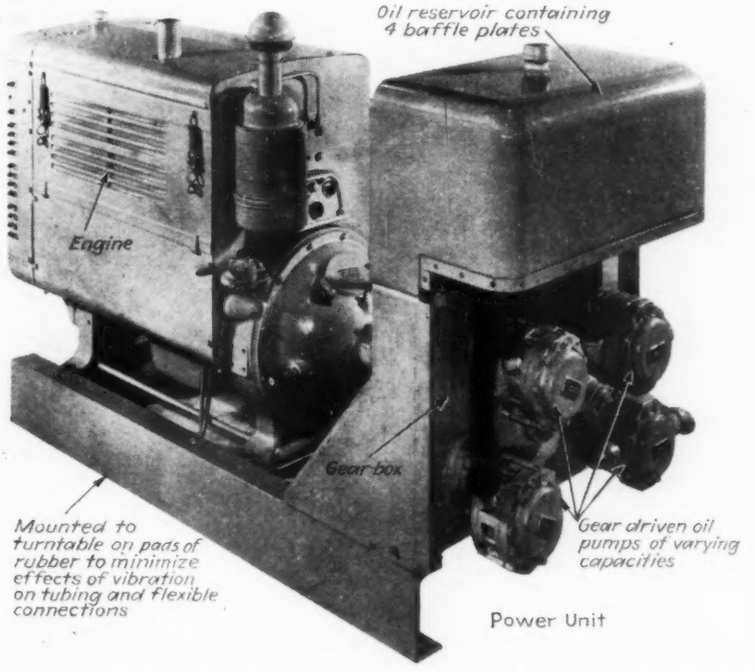
Turntable assembly furnishes a wide base for the rotating platform, which rests on four tapered hook rollers running in a one-piece, 4 ft. dia. circular track. Each roller is mounted in a cartridge that can be removed by unscrewing four bolts. The cartridge can be replaced without loss of alignment between roller assembly and bracket. Each cartridge comprises a bearing roller and shaft, housing, mounting plate and lubrication fittings.


Longitudinal rotation takes place on this ring
Rollers ride on exterior edges of telescoping section
Main Boom Section
Telescoping Boom Section
Rollers ride on tubing inside the main boom

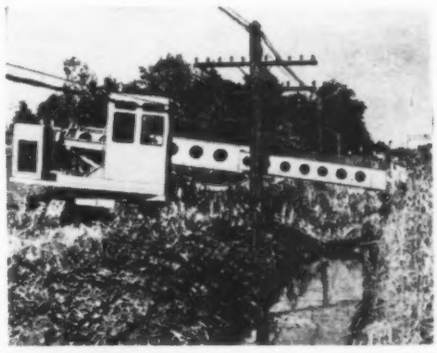
Triangular boom is welded of 3-$\frac{3}{8}$ in. O.D. seamless steel tubing and $\frac{3}{16}$ in. plate. Holes are pre-punched in the plates for lightness. Rims of the holes are flared to increase stiffness. Assembly is completed on an automatic welding machine. The telescoping boom section travels on six bearing rollers. These are mounted on brackets extending from the tube ends of the overlapping boom sections. Three internal and three external rollers bear against the tube components of the opposite boom member. At maximum extension of the boom, overlap is such that internal and external rollers are four feet apart. The Gradall can be used as a light crane by removing the tool from the end of the boom and substituting a chain or rope.


A
A
Boom Cradle
B
B
Raising and lowering of boom takes place about these trunnions
Longitudinal rotation of boom takes place through ring on main boom and these rollers
Section A-A
End bearing in cradle for main boom trunnion
Section B-B
Section through ring roller

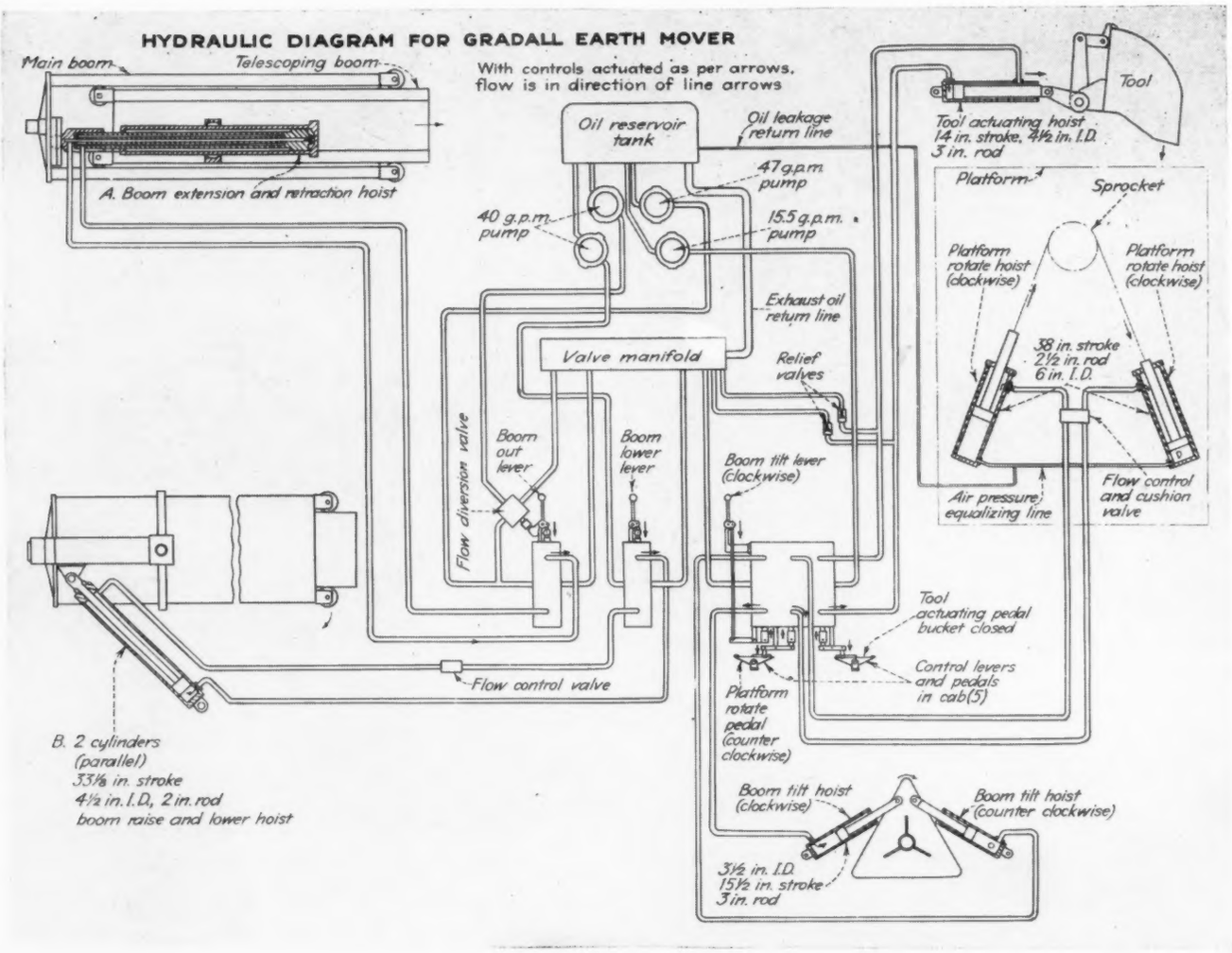
Boom cradle supports a trunnion mounted ring, which has four cast iron bearing rollers at 90 deg. intervals. The trunnion ring holds the stationary boom section by containing the steel ring mounted on the stationary boom. The latter ring is bolted to mounting lugs welded on the boom. Trunnions and the roller-ring arrangement enable raising and lowering of the boom as well as the rotation of the boom on its axis to angle the cutting tool.


Oil reservoir containing 4 baffle plates
Engine
Gear box
Mounted to turntable on pads of rubber to minimize effects of vibration on tubing and flexible connections
Gear driven oil pumps of varying capacities
Power Unit

Two pedals and three hand levers control all movements of the Gradall. A 48 **hp. gasoline** or diesel engine operates four spur gear hydraulic pumps. These pumps are nested on the face of the gear box driven by the engine. **Pump capacities** are predetermined by the size of the hoist cylinder they serve. Each pump has seamless steel tubing to deliver oil to an operating valve mounted on the manifold in the operator's cab. Flow of oil is controlled or diverted to the various hoist cylinders by manipulating the valves.



Earth Mover (continued)

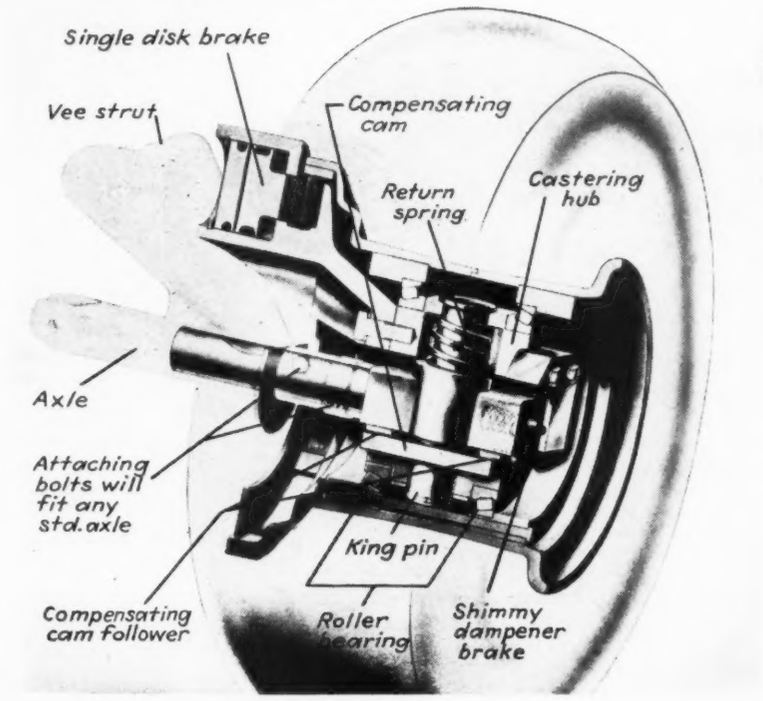

HYDRAULIC DIAGRAM FOR GRADALL EARTH MOVER
With controls actuated as per arrows, flow is in direction of line arrows
Main boom
Telescoping boom
A. Boom extension and retraction hoist
Oil reservoir tank
Oil leakage return line
47 g.p.m. pump
40 g.p.m. pump
15.5 g.p.m. pump
Exhaust oil return line
Valve manifold
Relief valves
Flow diversion valve
Boom out lever
Boom lower lever
Boom tilt lever (clockwise)
Flow control valve
B. 2 cylinders (parallel) 33⅛ in. stroke 4½ in. I.D, 2 in. rod boom raise and lower hoist
Tool
Tool actuating hoist 14 in. stroke, 4½ in. I.D. 3 in. rod
Platform
Sprocket
Platform rotate hoist (clockwise)
Platform rotate hoist (clockwise)
38 in. stroke 2½ in. rod 6 in. I.D.
Air pressure equalizing line
Flow control and cushion valve
Tool actuating pedal bucket closed
Control levers and pedals in cab(5)
Platform rotate pedal (counter clockwise)
Boom tilt hoist (clockwise)
Boom tilt hoist (counter clockwise)
3½ in. I.D. 15½ in. stroke 3 in. rod

Oil flows by gravity from reservoir to pumps. Pumps can develop pressures of 1,000 lb. per sq. in., but not until oil is diverted to a hoist cylinder by movement of an operating valve. When an operating valve is moved, oil is conveyed by seamless steel tubes or flexible hose to the cylinders involved. Six flexible hoses mounted on the left side of the boom cradle deliver oil for in-out motion of the boom, tilting action and tool actuator. When valves are in neutral position the oil is locked between valve and hoist cylinder thus fixing cylinder position. Oil delivered to valve in neutral is discharged into the manifold. Drain line from manifold spills the oil over four baffle plates in the reservoir to remove air bubbles and foreign matter present.

Change of attachments on the Gradall is a simple job requiring only the removal of a cotter pin to detach the ram, and the loosening of two nuts to open the split swivel journals. The one-half cubic yard bucket shown is of welded tube and plate construction and is only one-third the weight of a conventional bucket of same capacity. Continuous pull exerted in digging makes performance independent of bucket weight.

Castored Wheels Enable Directional Takeoff

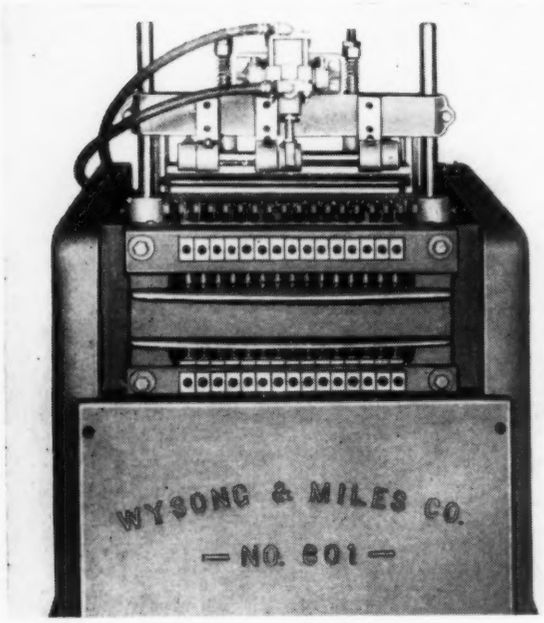
WITH THIS WHEEL-PIVOT COMPENSATION DEVICE, based on a kingpin-cam arrangement, an airplane can take off or land on a runway while heading into a cross-wind of as much as 25 degrees. The kingpin inclination with the plane in "tail low" altitude is 30 deg.; projection of pin axis intersects the ground ahead of tire contact point. Kingpin angle is still favorable to the desired pivot effect in the "tail high" takeoff position. This angle precludes any tendency of the wheel assembly to reverse under load, which is a normal reaction in castored wheels. A horizontal fixed compensating cam, surrounding the bottom of the pin, raises the airplane slightly as the wheels pivot, thus maintaining static stability. The wheel pivot compensation device was developed by Goodyear Aircraft Corp., Akron, Ohio, for the CAA. It adds no appreciable weight to standard landing gear design and can be applied to light planes.

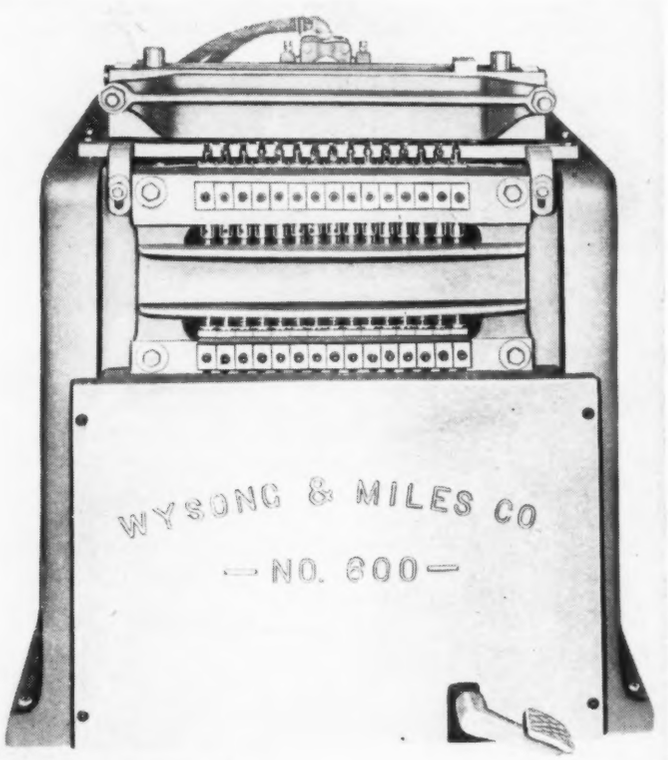


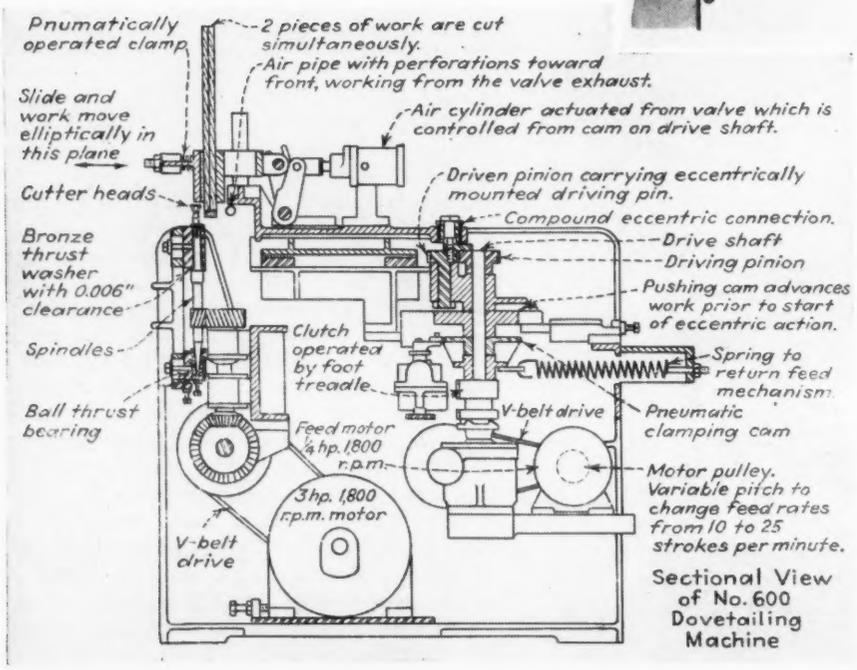
Static stability is accomplished by the cam follower, which is attached to airplane axle and rides in the compensating cam at the base of the kingpin. Main wheel bearings ride between the kingpin housing, or hub, and the wheel. Single disc brake cylinder is anchored to the hub and brake disk is splined to the wheel. This type of brake is used because it provides adequate space for the kingpin-cam arrangement. On the upper end of the kingpin and opposed to the cam follower is a coil spring. It returns wheels to the normal position parallel with the longitudinal axis of the plane when airborne and also aids in necessary vibration dampening. This cross-wind landing device is adaptable to the conventional light tripod landing gear.

Compound Eccentric for Elliptical Adjustment

AUTOMATIC, rounded type dovetailing of drawers is performed by the adjustable dovetailing machines designed and built by Wysong & Miles Co., Greensboro, N. C. Two units are required: Model 600 for dovetail tongues on drawer sides and Model 601 to make mating grooves in drawer fronts and backs. Each machine has a separately powered multiple spindle head fixed to the front part of the machine frame. The work is pneumatically clamped in a sliding head on the top of the frame. Feed motor and drive shaft are mounted in the rear of the frame. Cam action from the feed drive shaft forces the work through the cutters in the desired path. Operators' only duties are to load and unload the machine. As the bits become worn, an eccentric adjustment can reestablish the desired fit of mating parts.

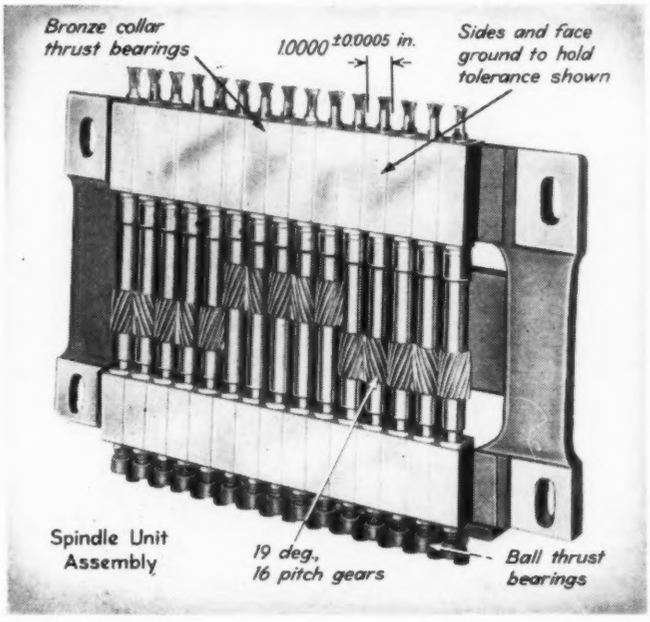


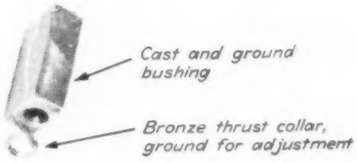



Pnumatically operated clamp
2 pieces of work are cut simultaneously.
Air pipe with perforations toward front, working from the valve exhaust.
Slide and work move elliptically in this plane
Air cylinder actuated from valve which is controlled from cam on drive shaft.
Cutter heads
Driven pinion carrying eccentrically mounted driving pin.
Compound eccentric connection.
Bronze thrust washer with 0.006" clearance
Drive shaft
Driving pinion
Pushing cam advances work prior to start of eccentric action.
Spindles
Clutch operated by foot treadle
Spring to return feed mechanism
Ball thrust bearing
V-belt drive
Pneumatic clamping cam
Feed motor ¼ hp. 1800 r.p.m.
Motor pulley. Variable pitch to change feed rates from 10 to 25 strokes per minute.
3 hp. 1,800 r.p.m. motor
V-belt drive

Sectional View of No. 600 Dovetailing Machine

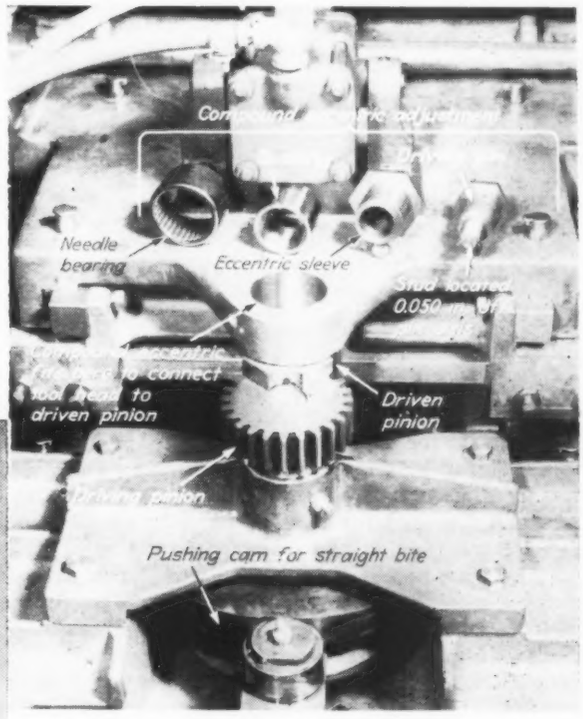
Work to be dovetailed is clamped to a slide having front to rear motion. The slide is mounted on rails that enable crosswise motion. The feed drive shaft is fastened by an eccentric connection to the rear end of the slide. A ½ hp. motor drives this vertical shaft through a worm gear assembly. The grooving unit is required only to make a dovetail groove, therefore the work is advanced into the cutters and withdrawn in a straight line. The tongue cutting machine has a more complex motion to form the semi-elliptical mating projection. Major parts of the frame are aluminum castings for machinability. Box construction is used for rigidity and compactness and there are no overhanging parts to interfere with the operator. Floor space only 36 x 40 in. is required for the machine.

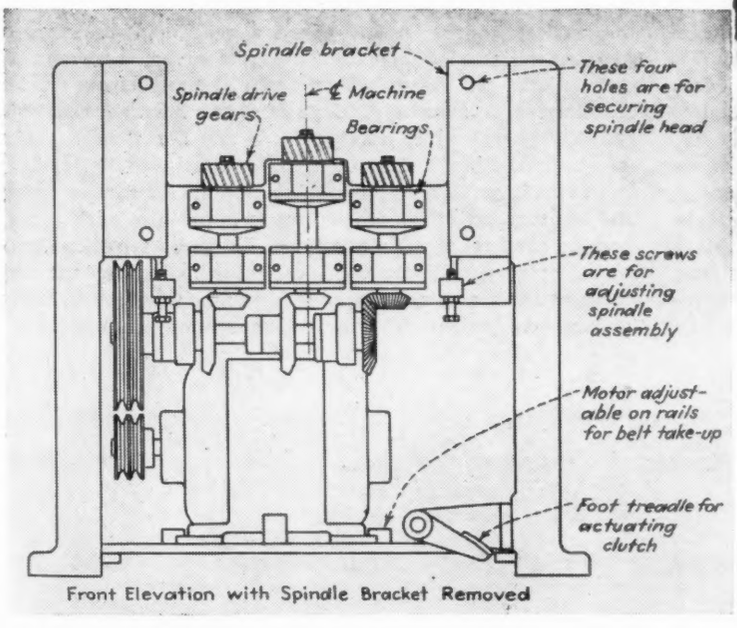

Bronze collar thrust bearings
1.0000 ±0.0005 in.
Sides and face ground to hold tolerance shown
Spindle Unit Assembly
19 deg., 16 pitch gears
Ball thrust bearings



To cut dovetailed tongues, two drawer sides are placed in the clamp back to back. The work is advanced through the cutters in a slightly elliptical path. Circular component of the motion is provided by bolting the driving pin off center of the driven pinion. Elliptical quality is obtained through an eccentric sleeve compounded with the eccentricity of the driving pin stud. This stud axis is 0.050 in. off the driving pin axis and fits in the eccentric sleeve that is mounted in a needle bearing in the slide. Turning the sleeve establishes major degrees of eccentricity. Turning the pin changes eccentricity of the stud for fine adjustment to compensate for the normal cutter wear.

Spindles are mounted in a cast iron frame which is removable after loosening four bolts. The spindles are cast of crucible steel, Maxwell 3½. Integral helical gears, 16 pitch, are ground after hobbing. The 19 deg. angle provides a rubbing contact that is self cleansing and removes wood dust, which would pack if bevel gears were used. Spindles are full floating and rotate at 5000 r.p.m. They tend to climb because of the gear angle, so takeup is provided for both spindle ends. Diecast spindle bushing housings are ground on face and sides to hold center-to-center spindle distances at 1.000 ±0.0005. One shot lubrication without machine shutdown.



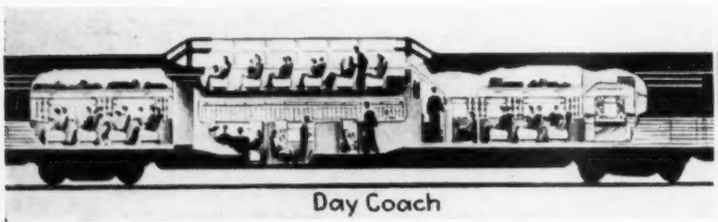

Spindle bracket
Spindle drive gears
℄ Machine
Bearings
These four holes are for securing spindle head
These screws are for adjusting spindle assembly
Motor adjustable on rails for belt take-up
Foot treadle for actuating clutch
Front Elevation with Spindle Bracket Removed

Spindle drive unit is contained in a one-piece casting. Spindles are driven in three separate sets by the three drive gears. This distribution lowers individual loads on the driving gears as compared to a single drive gear design. Foot treadle operates the one-cycle clutch that engages the feed drive shaft. When the clutch is engaged, the feed shaft rotates cams that operate the pneumatic clamp and push work into position. Speed, 20-25 cycles per min.

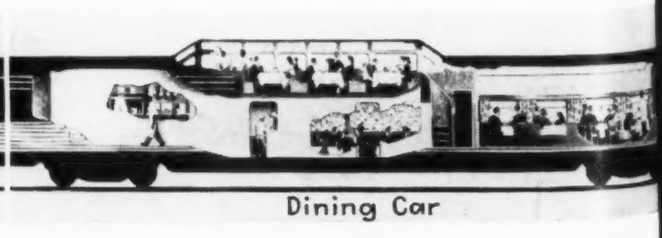
Design Features

Of the Train of Tomorrow

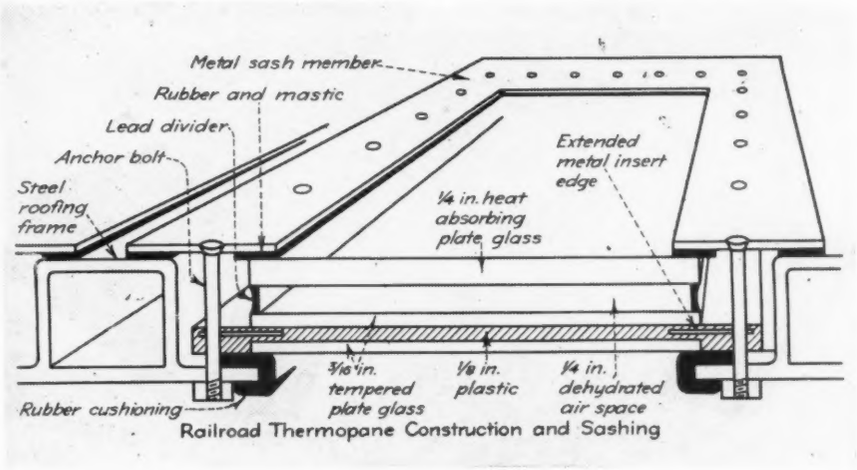
THE "TRAIN OF TOMORROW" is an experimental project of General Motors through which to try out advanced ideas for improvement of railway travel. The train was designed by GM in cooperation with various manufacturers. Cars were built by Pullman Standard Car Manfacturing Co., and the unit, powered by an Electromotive diesel locomotive, is now touring the country. Most apparent innovation is the "Astra Dome," projecting above the roof of each car. It is a glassed-in upper compartment, built to seat 24 passengers above roof height. In these domes the passengers view the landscape from a vantage point that is expected to enhance the pleasure of railway travel. By adding a depressed floor, this construction enables a 4-level car: dome, conventional level, ramped passageway beneath one side of the dome and a compartment two steps down from the passageway. It is believed that the variety of movement afforded will help to remove monotony from long trips. The train is not a revamped conventional job, but has been newly designed from trucks up. Passenger accommodations offer the latest in comfort. Each chair reclines to nine positions and has an adjustable foot rest. Baggage door on the day coach speeds loading and unloading. Sleeping car roomettes have chairs or sofas and lavatory facilities. Cooled water is piped to each room. Lounge car has movable furniture, FM radio telephone and wire recording equipment. Loud speakers in each car are connected to radio, recorder and public address systems. Each car operates facilities from its own diesel-powered generator.



Day Coach

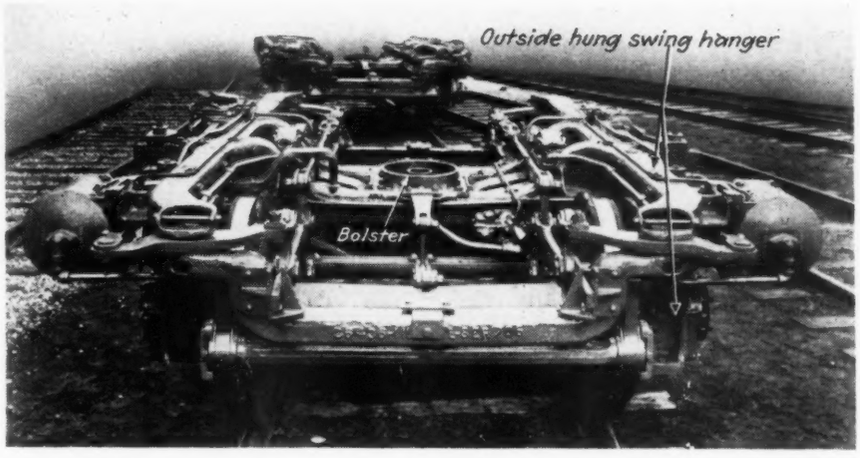


Dining Car



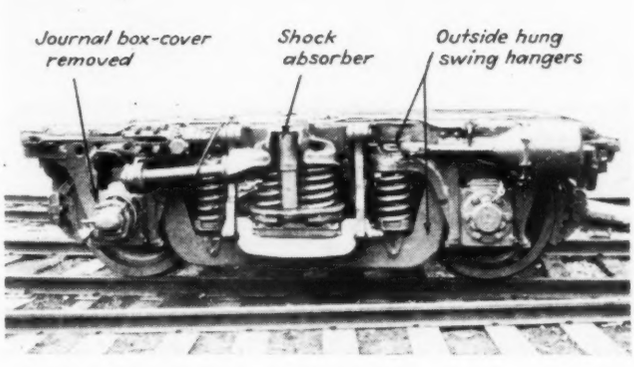
Railroad Thermopane Construction and Sashing

Glass, surrounding the passenger on all sides and above, raises problems of safety, glare and heat from the sun. GM and Libbey-Owens-Ford Glass Co. developed an insulated railroad window glass for this application. Outside sheet is tempered to have 3 to 5 times the strength of regular plate glass. It is also slightly darker to reduce glare. Inner pane is a laminated, tempered safety glass in which the inner layer is polyvinyl butyral, also tinted to reduce glare. The multipane unit is sashed in the dome superstructure by a flexible construction. Under impact this sashing yields rather than shears. It is claimed these panes resist hurled objects better than steel used in the roof.

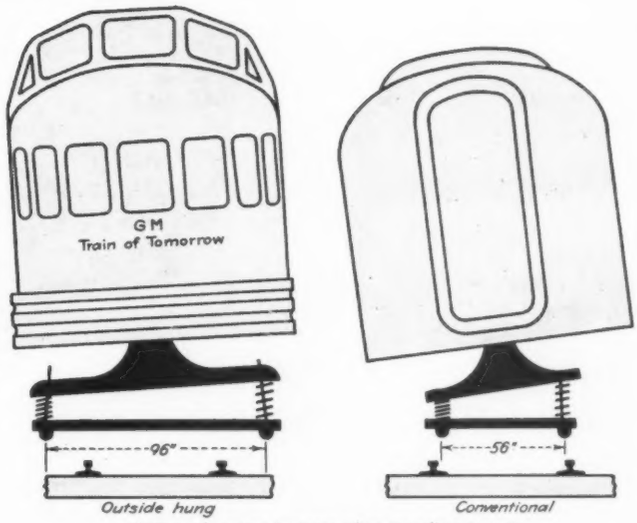


Lower ends of the hangers are further apart than the top ends. On a curve, centrifugal force makes the inside hanger swing in and downward, causing the car to bank. Degree of banking thus automatically is adjusted to the curve and train speed.

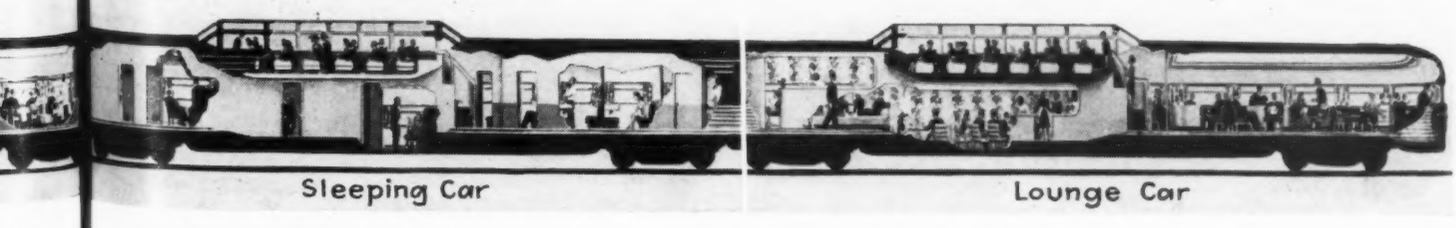
Under identical test, a car with standard hangers swayed 14 in. off the roof center line against 3 in. for a car on outside hangers. Coil springs and airplane type shock absorbers contribute to smoother riding of the car.



Swing hangers hung outside the truck frame were originally developed by Electromotive Division of GM for diesel locomotives. They are applied here to passenger cars because they add to stability and increase ability of the truck to dampen road shocks and side sway.

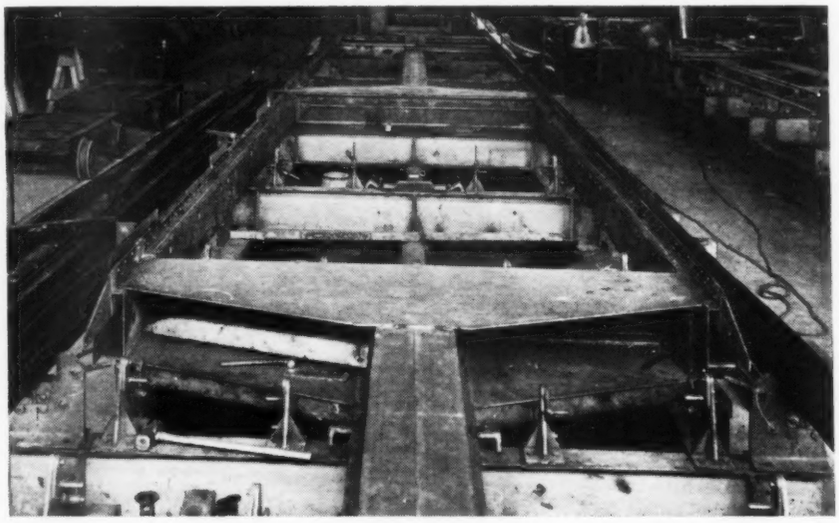


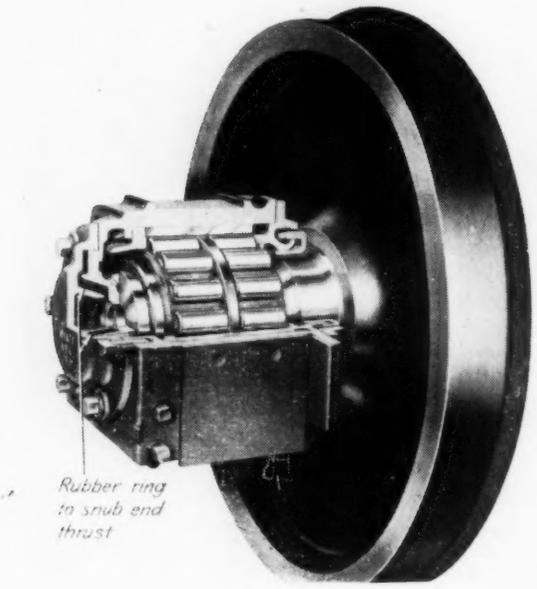
Action of spring hangers when rounding a curve



Train of Tomorrow (continued)

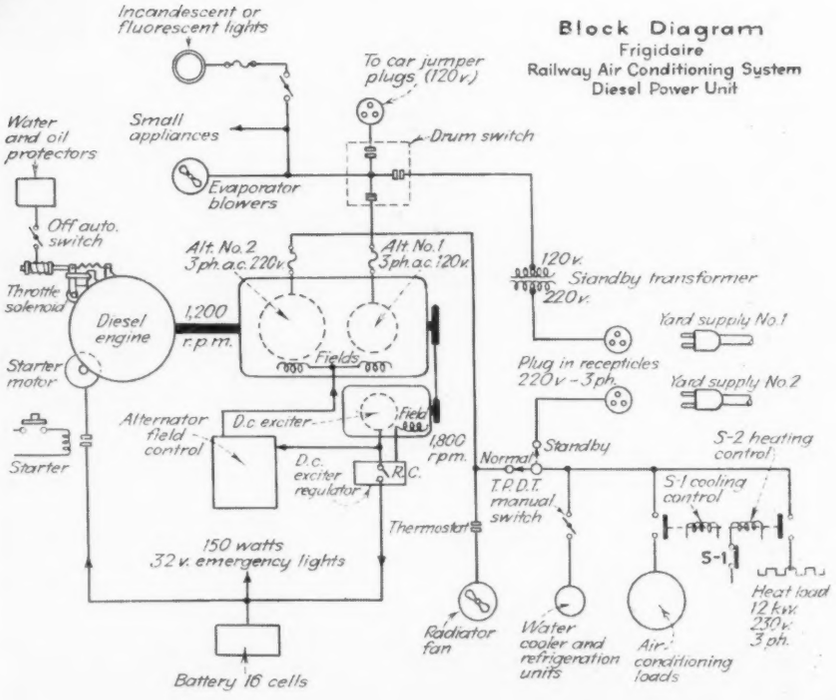
Depressed floors necessitated a new frame construction. Instead of a steel beam from coupler to coupler, structural members are split to pass around the depressed region. Under compression test of 800,000 lb. the center of the car floor temporarily deflected 0.45 in. above bolster center height. This is within the 1.00 in. limit regarded as the maximum allowable. Under torsional test the car was supported on the side sills. The two diagonally opposite supports were dropped and deflection between bolsters was 0.23 inch.

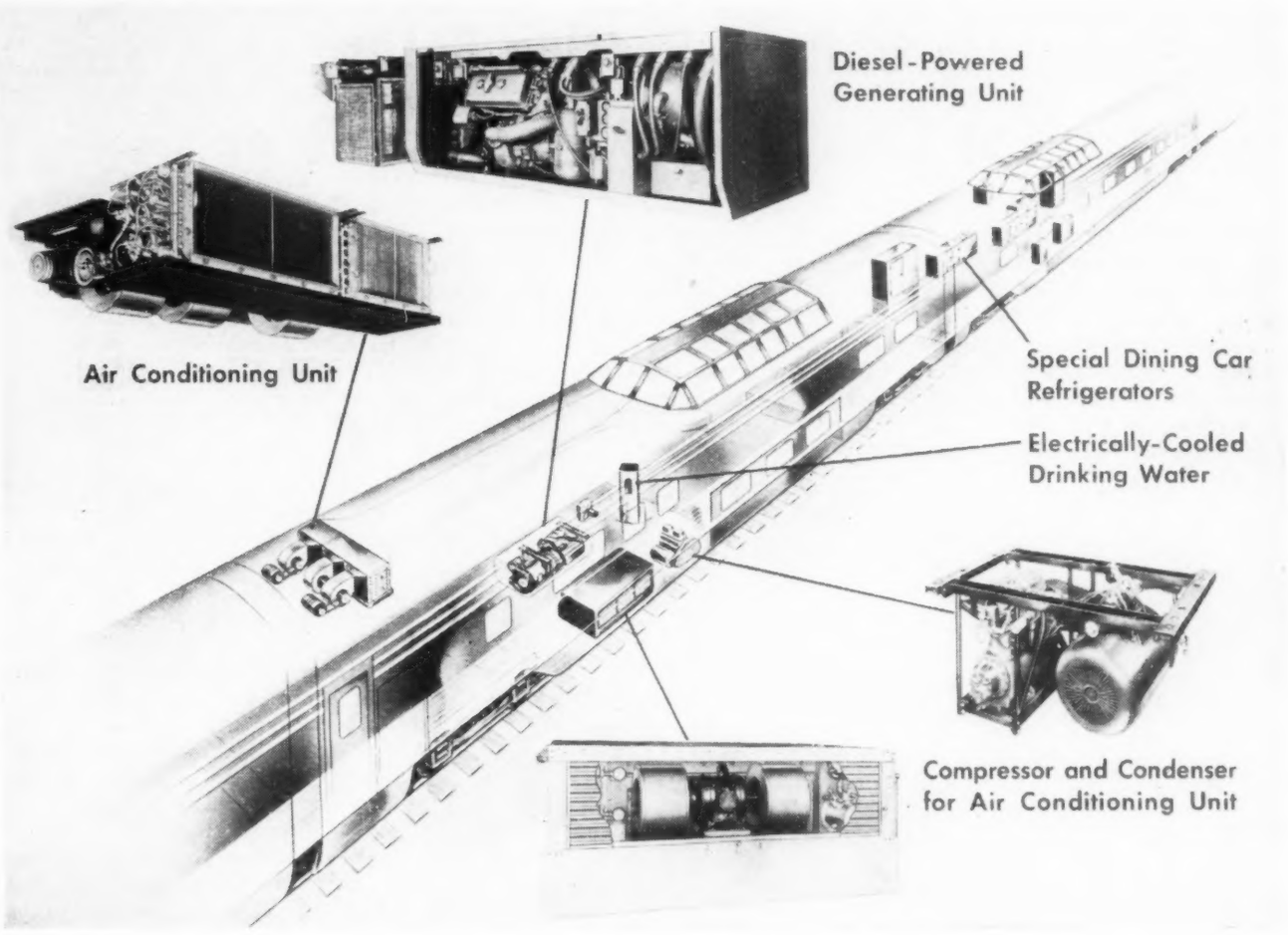




Journal boxes used on both locomotive and cars differ somewhat from the conventional Hyatt design. A resilient synthetic rubber ring has been interposed between axle thrust block and outside cover of the journal box. This ring replaces the spring pack usually used on Hyatt locomotive journal boxes to cushion sidewise shocks. On the passenger car journal boxes, in which the spring pack was never used, introduction of a cushioning member results in a definite improvement in riding quality. Rollers in each bearing are kept aligned and properly spaced by a one piece separator of special alloy bronze. These separators are cast with no joints of any kind and with liberal cross sectional areas. Bearings are lubricated with straight mineral oil carried up from the oil reservoir which is formed by the lower part of the journal box housing. The conventional smoke or stench bomb heat indicator used on all types of roller bearing journal boxes have been replaced by inside-the-car devices for reading the temperature in the journal boxes.

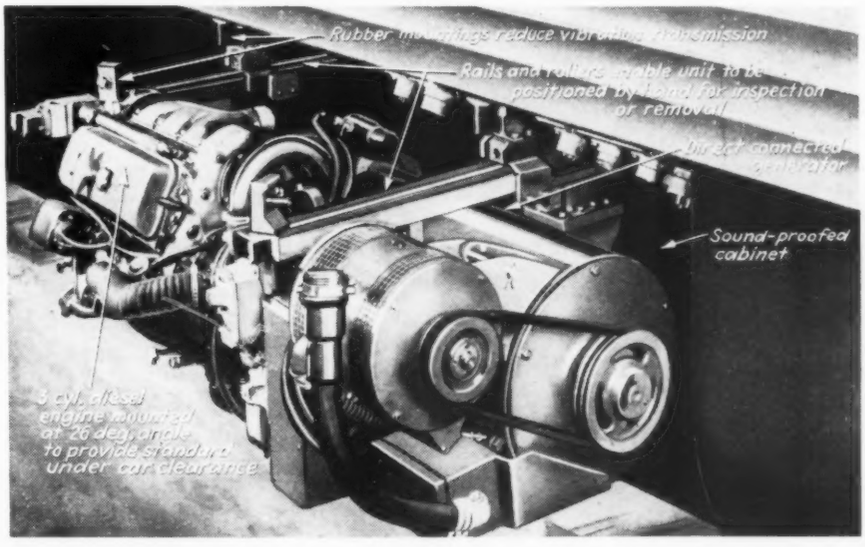
Each car has a self-contained, diesel-driven "power package" that furnishes power for lights, ventilation and air conditioning at all times, even though the car is cut off from the train. Independently driven units compared to axle-driven equipment save 600 hp. on a 12 car train, thus permitting faster acceleration. Reduction in battery size, required here only for cranking, saves 3,500 lb. per car. Fluorescent lighting also can be used without auxiliary converting equipment. Two alternating current generators are built on a common shaft in one frame. The 15 KW generator furnishes 220 v., 60 cycle current for air conditioning and refrigeration equipment while a 10 KW generator supplies 115 v., 60 cycle current for lights, radios, shavers, and ventilation.




Diesel-Powered Generating Unit
Air Conditioning Unit
Special Dining Car Refrigerators
Electrically-Cooled Drinking Water
Compressor and Condenser for Air Conditioning Unit

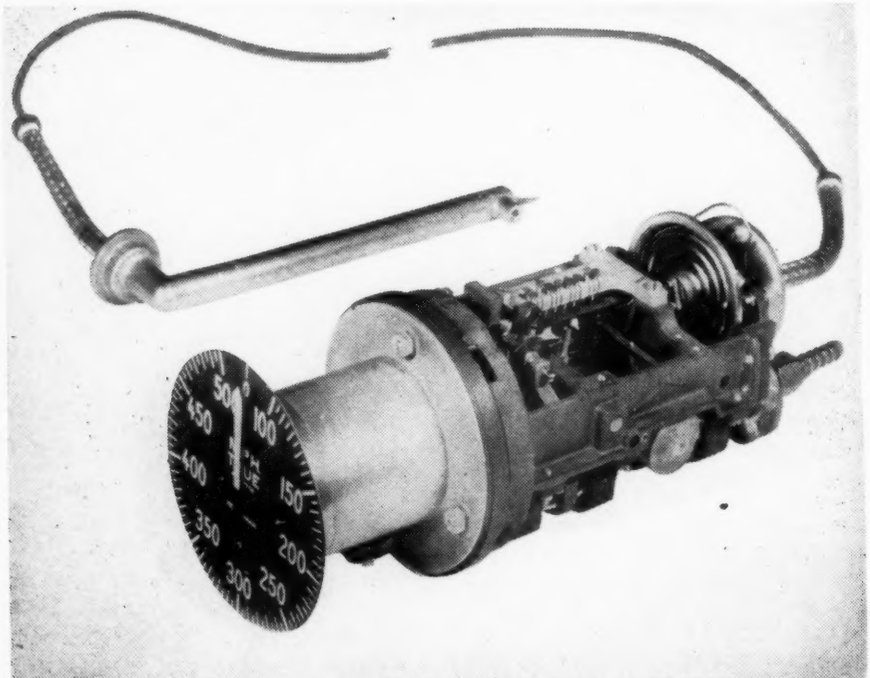
Air conditioning unit is located in the car ceiling; the condenser is under the car. Air ducts pipe the conditioned air to various parts of the car. Cooling capacity of the system is 10 tons, 6 for the lower space, 4 for the dome compartment, which requires this capacity because of exposure to the sun. Mechanical refrigeration is applied throughout the train so that cooled fresh water is available at the faucet in all compartments. The system was developed by Frigidaire. The individual car generator units **enable use of a-c motors** and standard electrical appliances. Dining car, in addition to having its own diesel-driven generator for electric lighting and air-conditioning, also is equipped with a separate unit that furnishes current for an electric kitchen. This plant is housed in a compartment 6 ft. long and 3 ft. wide at the end of the car, to one side of the vestibule. It is powered by a diesel engine direct connected to a 1,200 r.p.m., 37½ kw generator. Dining car dome seats 18 and is served through a dumb waiter. Private dining room in the depressed portion seats 10, the main section seats 24 persons. Triangular tables and diagonal alignment simplify seating.

Each minute 400-500 cu. ft. of waste air at 80 deg. F. are drawn from the car through the generator and discharged into the engine compartment. This provides warm air for engine operation and maintains an even operating temperature for all equipment. Cabinet ventilation is performed by a fan on the engine crankshaft. Water radiator for the engine is mounted outside the cabinet and the radiator fan is electrically operated. Controls are located both in the car and in the engine compartment. Unit rolls from place on rails.

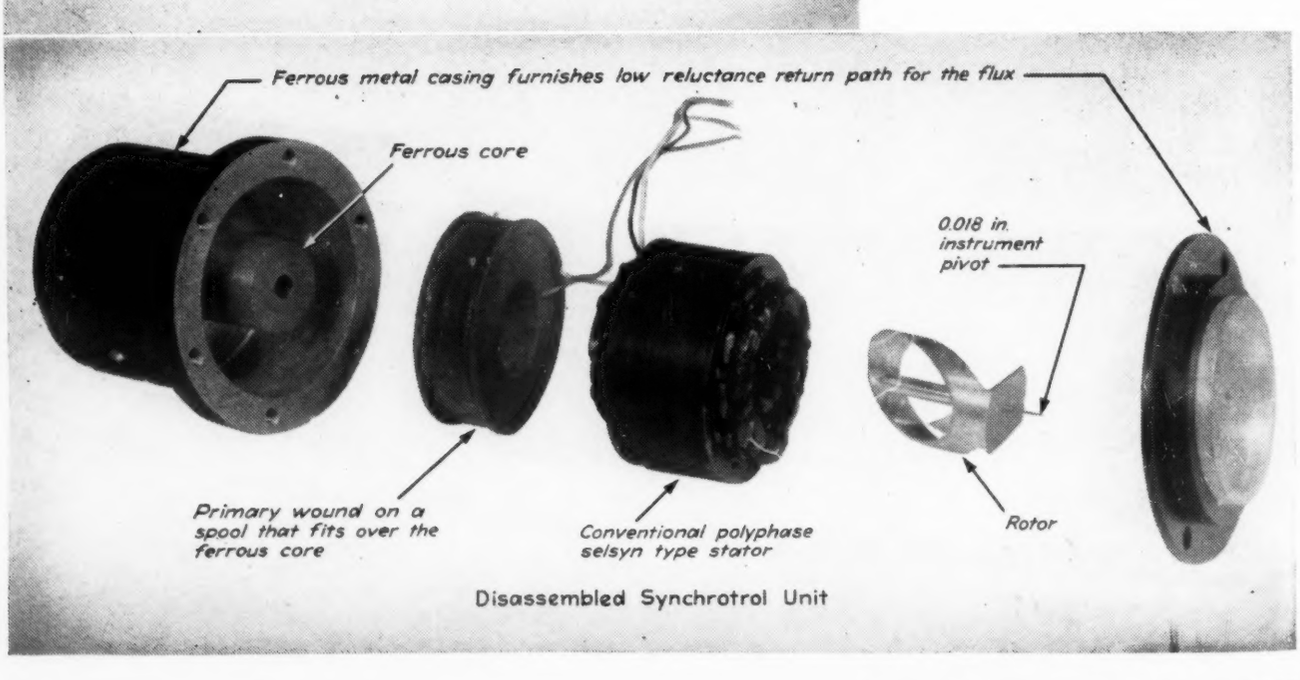

Rubber mountings reduce vibration transmission
Rails and rollers enable unit to be positioned by hand for inspection or removal
Sound-proofed cabinet
3 cyl. diesel engine mounted at 26 deg. angle to provide standard under car clearance

Oblique-Section Rotor For Lightweight Synchro Motor

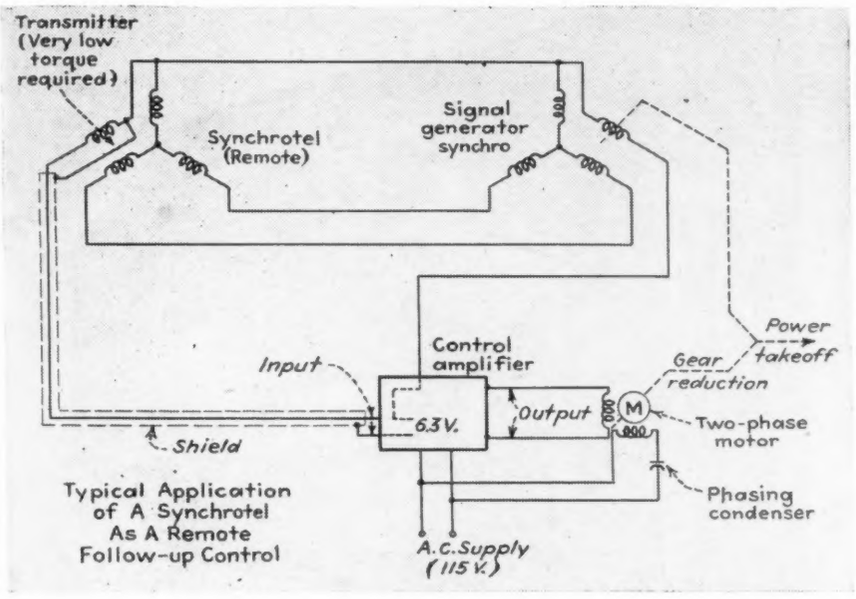
THE SYNCHROTROL UNIT was developed to reproduce the pointer position of sensitive aircraft instruments remotely and to provide a high torque at the remote shaft for operating recorders and computing mechanisms without affecting the instrument's accuracy readings. The unit is a synchro motor with an extremely lightweight, low inertia rotor and no electrical reaction; developed by Kollsman Instrument Division, Square D Co., Elmhurst, N. Y. The top figure shows an instrument mechanism, removed from its case, wherein the synchrotel rotor shaft replaces the normal pointer shaft of a true airspeed indicator. The dial and pointer are retained for the pilot's use while a servo system, as shown below, furnishes a high torque remote indication for a computer input or other recording instrument use.



Rotor is an oblique section of a hollow cylinder with one end left on as a base for the shaft. It is of pure aluminum, providing high electrical conductivity with a weight of 1.7 grams and correspondingly low moment of inertia. The shaft is terminated in 0.018-inch instrument pivots that run in sapphires. Since there are no brushes and no electrical reaction, positioning torque need be sufficient only to overcome the friction of these jewelled bearings. High order angular accuracy is obtained because the rotor, with its peculiar shape, is perfectly skewed with respect to the pole pieces and hence introduces a minimum of harmonics. Secondly, radial play in the rotor shaft, or rotor eccentricity, have negligible effect on flux distribution because the iron to iron air gap is not affected. Residual voltage at "null" is equivalent to that of other synchros.


Ferrous metal casing furnishes low reluctance return path for the flux
Ferrous core
0.018 in. instrument pivot
Primary wound on a spool that fits over the ferrous core
Conventional polyphase selsyn type stator
Rotor

Disassembled Synchrotrol Unit



Typical Application of A Synchrotel As A Remote Follow-up Control

In operation the unit functions as a control transformer synchro in the circuit as shown. The stator windings are excited with alternating voltages of varying amplitude from the stator of a cooperating, a-c supplied synchro motor, which produces a resultant radial flux. Any of this flux that links the single turn loop of the rotor induces a current in the loop, which in turn produces an axial component of alternating flux in the cylindrical core. This flux induces in the primary winding an a-c voltage, whose amplitude is a sinusiodal function of relative positions of the rotor and the resultant stator field, hence the signal generator rotor angular position. The voltage is amplified to actuate the control phase of the two-phase servo motor that drives signal generator to position giving a null in the synchrotel rotor.

Random Notes

Leaks in vacuum and pressure systems in the order of 10-8 cc. per sec. can be detected with the portable instrument developed by Consolidated Engineering Corp., Pasadena, Calif. the instrument is a simplified mass spectrometer for detecting helium. A special ionization chamber accomplishes electronic separation of helium molecules, by their mass, from dissimilar molecules in the atmosphere. The instrument is applied to an evacuated system in which helium has been introduced.

Stainless steel springs, oil impregnated bearings and hinged dust covers are incorporated in the new traffic signal controllers announced by General Electric.

Construction of a hot air engine on a commercial basis has been announced by Philips Incandescent Lamp Works, Eindhoven, Holland. The efficiency is somewhere between that of the gasoline and diesel engines. Main advantage is that fuel can be either gasoline, oil, methyl alcohol or coal gas. Combustion takes place outside the cylinder. There is no chemical influence on the pistons and cylinders, as they remain cold and the air remains pure.

Atmospheric corrosion tests conducted at the Kure Beach, N. C. by International Nickel Co., Dow Chemical Co. and Carnegie-Illinois Steel Corp. have strikingly emphasized that surfaces exposed to sun and wind do not corrode, in most cases, as rapidly as bottom and interior surfaces. Reason is that all the surfaces exposed to the atmosphere receive approximately equal condensation, but wind and sun dry the outer surfaces quickly. The condensate remains on the bottom and interior surfaces for a longer time, thus prolonging the corrosion action.

Observations on thousands of test plates show that the darker the color of the rust, the less the weight loss through corrosion. Generally the darker colors are indicative of higher nickel content.

Die cast magnesium does not have the accelerated corrosion rate sometimes associated with other magnesium castings. The die castings do not contain the flux inclusions that have been found to be a starting point for corrosion in other types of castings.

Turbo-supercharged diesel engines are used in the new locomotives built by Alco-G.E. and Baldwin-Westinghouse. As in aircraft engines, exhaust gases drive the turbine. Alco's new "6000" locomotive also features amplidyne control and regenerative braking. The energy generated in braking is dissipated by air cooled grids.

A universal automatic machine for the production of flexible goffered hose from thin-walled tubes of stainless steel, brass, aluminum and other metals has been constructed in the USSR. The machine can produce an airtight flexible metallic hose with walls 0.08 mm. thick. The goffering effect on the tube is produced by a rotary roller, which makes hollows and waves on the smooth surface of the tube. After the tube is covered with waves along its length, the machine presses it automatically and the flexible hose is then ready for use. In a longitudinal cross-section each edge appears as closely-packed reverse bends, somewhat resembling a series of figure eights. The machine produces flexible hose of various diameters from 9 to 25 mm. with waves of any profile and pitch. Seamless tubes and ordinary metallic straps can be used as material for its production. The tubes will be used as reliable high-pressure pipes for liquids and gases. Owing to their flexibility, they have a high vibration-absorbing capacity. They can be successfully used as heat-exchangers.

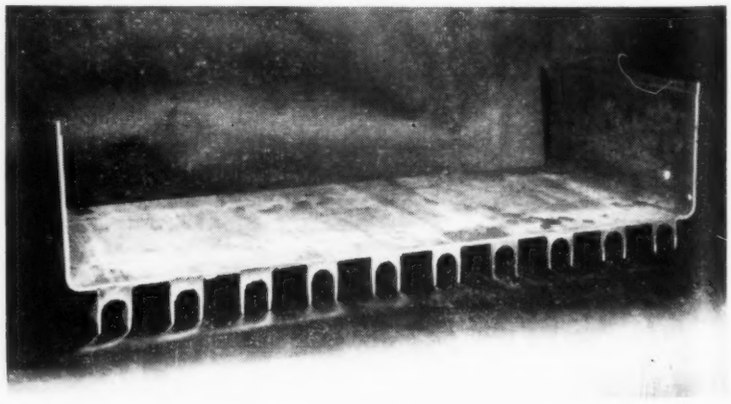
Corrosion cracking that frequently occurs in welded magnesium structures can be obviated by annealing ½ hr. at 400 F. This can be combined frequently with a paint baking operation.

Multicolor finishing on aluminum and some alloys to simulate almost any desired color, grain or effect, has been announced by Altones, Ltd., Glasgow, Scotland. In the process anodizing and dyeing are combined to produce the combined color and surface relief.

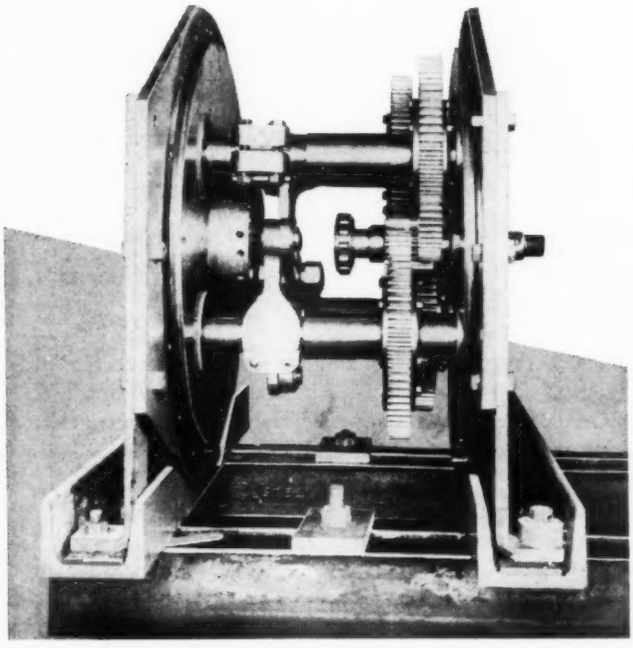
Extruded Aluminum Freezer Compartment

AN UNUSUAL METHOD of joining steel evaporator coils to an aluminum freezer compartment is used in the 1947 Servel gas refrigerator. To obtain good heat conduction with an economical construction, Servel, Inc., Evansville, Ind., has devised an extruded aluminum finned compartment, in which the fins are formed around the freezer coils by a simple press operation, holding them in firm contact.

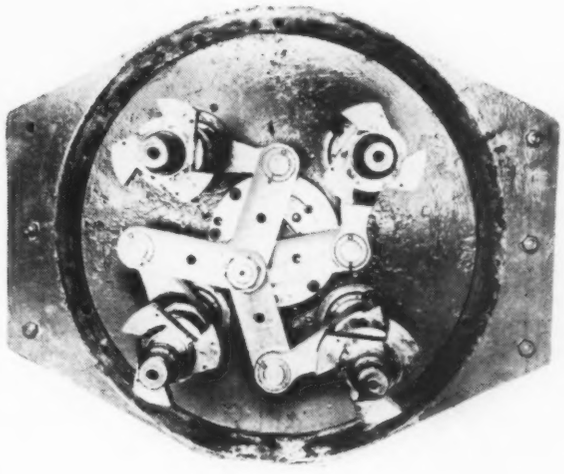
The extrusion is too wide for standard hot pressing or extruding equipment, therefore it is extruded with sides folded flat. These sides are later straightened to the position shown. The extended fins are pressed around the steel coils in a large punch press. This extrusion forms the compartment at the top of the refrigerator in which ice cubes are made, and minimizes joints in the compartment.



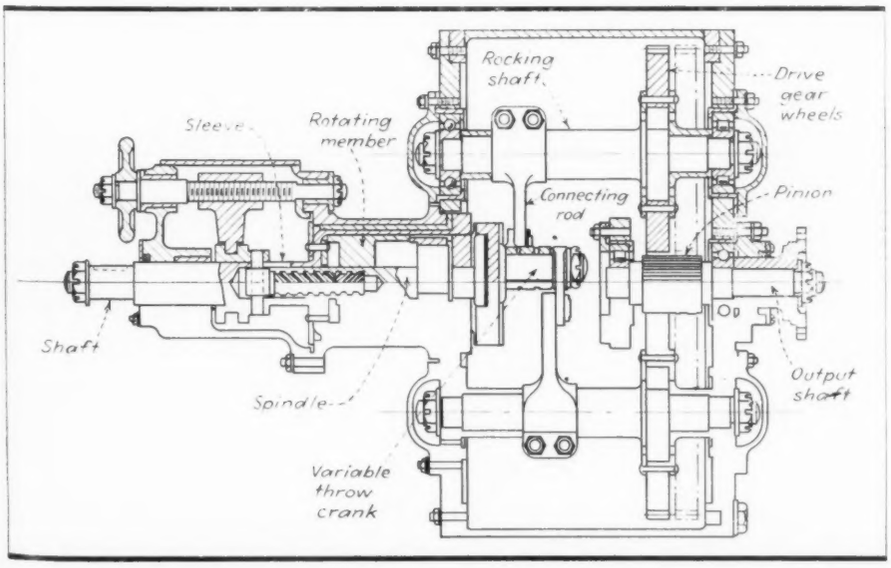
Speed Gear Regulated Through Variable Throw Crank



ONE-WAY DRIVE GEARS, mounted on rocking shafts, drive the pinion of the variable speed gear, developed by McEwan & Neave, Glasgow, Scotland. The speed gear will transmit 7 hp. at constant 500 r.p.m. input with speed of the output shaft infinitely variable from zero to 1,000 r.p.m. Construction comprises four one-way drive gears that mesh with a central output pinion. Each drive gear is mounted on a rocking shaft, with a crank connecting rod joining each shaft to a variable throw crank in the main housing. This crank is carried on a spindle, eccentrically mounted in the rotating member, and adjustable by axial screws in the shaft.



Reciprocating speed of the connecting rods and rocking shafts is constant. Variable factor is the length of the driving or "working" arc imparted to the pinion by the drive gears. This arc is lengthened by increasing eccentricity of the spindle in the rotating member, thus lengthening connecting rod stroke. Number of revolutions imparted to the pinion is greatest with maximum eccentricity. Four drive gears are used so that with the shortest stroke there is always an overlapping drive from two of the gears.



Two sleeves in the rotating member enable adjustment of the main crank. When the handwheel is turned, axial movement of the screw increases or decreases eccentricity of the spindle with respect to the axis of the rotating member. In action, the drive imparted by throw of the main crank is transmitted to the connecting-rods, links, rocking shafts and drive gears. Each drive gear "free-wheels" on the pinion during the return motion of its rocking arm. Drive gears are attached to rocking shafts through one-way drive rollers, not shown.

Illustrations by courtesy of The Engineer

Special Control Circuits for Motors May Aid Machine Performance

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When standard motor controllers are inadequate, specially devised control schemes can usually provide any wanted operational requirement such as cycling, sequencing, or preferential selectivity. Applications of special motor control circuits discussed include self-contained drives, programmed multiple units, multispeed drives, remote, and centralized control.

MANY industrial control requirements that cannot be met by standard motor controllers are easily provided by specially designed control circuits.

By proper circuit design, standard control devices and components can provide precise time delay operation, selector control, compelled sequence starting, or other operational characteristics that are needed for the best performance of the machine. These specially designed or modified standard a.c. or d.c. motor control systems are often for self propelled units, heating and ventilating systems, machine tools, pumps, hoists, and similar motor operated equipment. Some of the typical application requirements of special motor controls are analyzed in the following discussion and the functions of the component devices in the special circuits are explained by a typical schematic diagram.

Self-Contained Drives

Safety, conservation of power, and precise control of speed are often required for certain electrified industrial products, especially those that are self propelled. An electric truck, for example, uses the special circuit shown in Fig. 1 to obtain this combination of advantages. The special circuit uses magnetic control for the traction motor and the lift-and-tilt motor.

Power for the motors and the builtin control is supplied by a 30 volt battery, such as commonly used in industry. The controls for the series traction motor provides three speeds in either forward or reverse. Pilot control of the forward, reverse, and accelerating contactors is obtained by a cam operated traction control switch. The series motor driving the hydraulic pump for lifting and tilting the truck's loading platform is controlled by interlock switches.

In Fig. 1, with the safety switch closed, forward starting in slow speed is done by moving the traction switch to Position No. 1. This closes the forward line contactor *FOR*, connecting the traction motor field and the starting resistors in series with the motor armature. In the second speed forward position, the accelerating contactor, *AC* 1, closes, short-circuiting the starting resistor and the truck accelerates. In the third position, accelerating contactor, *AC* 1, drops out, reinserting the starting resistance and at the same time closing accelerating contactor *AC* 2. When closed, *AC* 2 connects the two series fields and the starting resistor in parallel for full speed forward.

Moving the control switch to one of the three reverse speed positions reverses the truck. As shown in the Table in Fig. 1, this closes the reverse contactor and the proper accelerating contactor corresponding to the particular speed step.

The lift-and-tilt motor for the hydraulic drive is controlled by the interlock switches. When either or both of these interlock switches are closed, the coil of the lift and tilt contactor is energized thus starting the motor driving the hydraulic pump.

The directional contactors are electrically interlocked; their magnetic blowouts increase the life of the contacts and minimize contact maintenance. Accelerating contactors, *AC* 1 and *AC* 2, have both electrical and mechanical interlocks.

Selective Control

Special control circuits can equalize the mechanical wear in multi-unit drives, simplify maintenance, and minimize the danger of shutdown in continuous processes. Typical applications include complex pumping systems for deep well pumps, house water pumps and refrigeration compressors. The typical system shown in Fig. 2 distributes the mechanical wear between several controllers, motors and pumps. In the actual installation three motor controllers, motors, and pumps were used, but for simplicity only two are shown. The two squirrel cage induction motors driving the pumps are controlled by magnetic across-the-line starters. Remote control permits "Manual" or "Automatic" operation, and a switch selects one of the units as the "lead" pump. Either pump can be shut down for maintenance purposes without disturbing normal operation. Both pump controllers have overload and low voltage protection.

By means of the two 3-position pushbutton stations manual or automatic operation can be selected. With the pushbuttons in the "Manual" position, the pressure switches are bypassed in the control circuit. This permits operation of both motor controllers simultaneously and the pressure switches and selector switches have no control of the operation. In

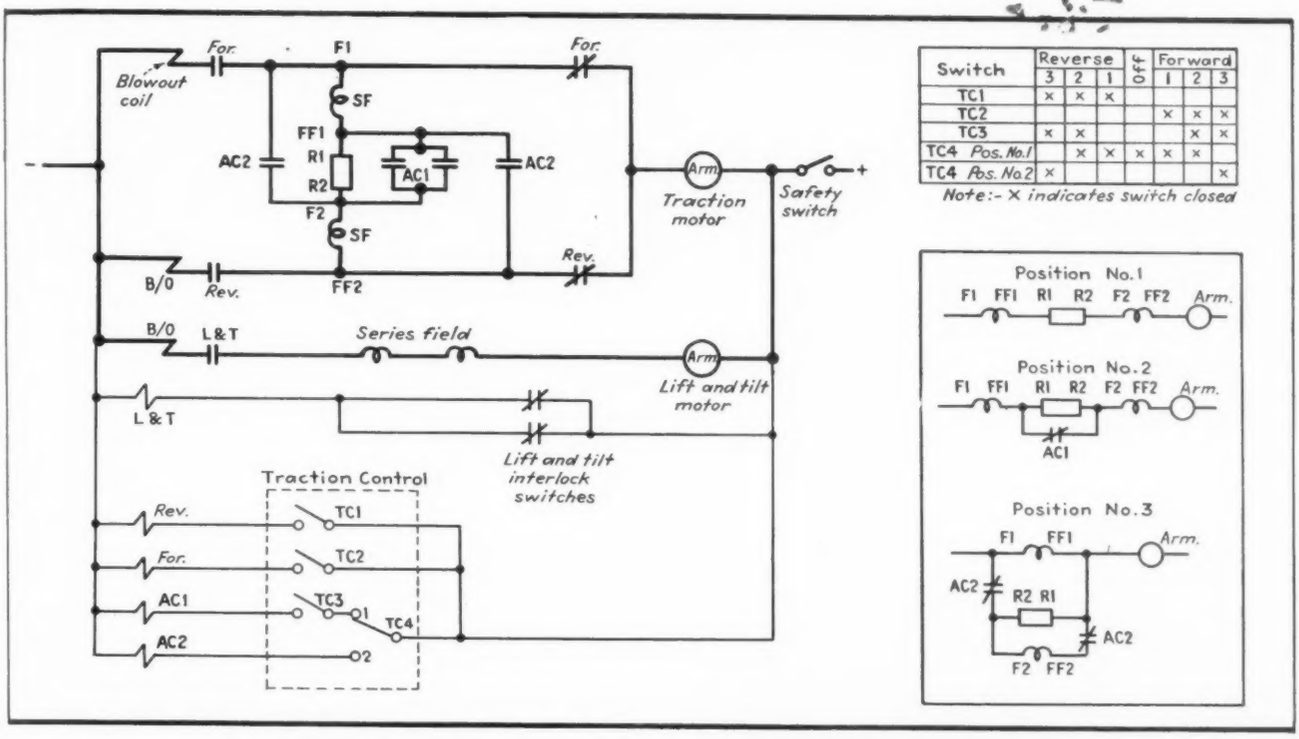


Fig. 1—Control for electric truck for main traction motor and lift-and-tilt motor.

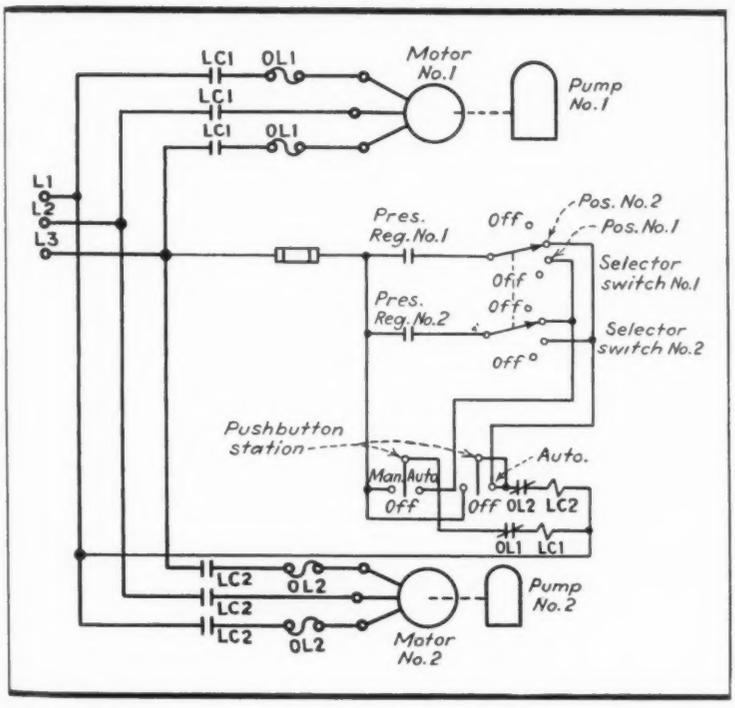


Fig. 2—Selective control equalizes mechanical wear of two pumps.

Fig. 3—Testing a special motor control circuit.

the "Automatic" position, the starting and stopping of the motor is controlled by the opening and closing of the pressure switches.

The selector switches determine which pump has control as the "lead" pump. For example, assume that pressure switch *PWS* No. 1 is set to close at 20 and open at 30 lb. per sq. in., and that pressure switch *PWS* No. 2 is set to close at 15 and open at 30 lb. per sq. in. With both pushbuttons on "Auto" and the selector switches on position number 2, No. 2 pump has control. When the pressure in the tank drops below 20 lb. per sq. in., motor No. 2 starts driving the pump until the pressure increases to 30 lb. per sq. in., which stops the motor. If excessive demand reduces the pressure below 15 lb. per sq. in., pressure switch *PWS* No. 2 closes starting motor No. 1 until the pressure increases to 30 lb. per sq. in. The control can be changed from one motor controller, motor, and pump to the other on successive days to divide the wear equally.

Both motors are protected against overload. If motor No. 1 is over-

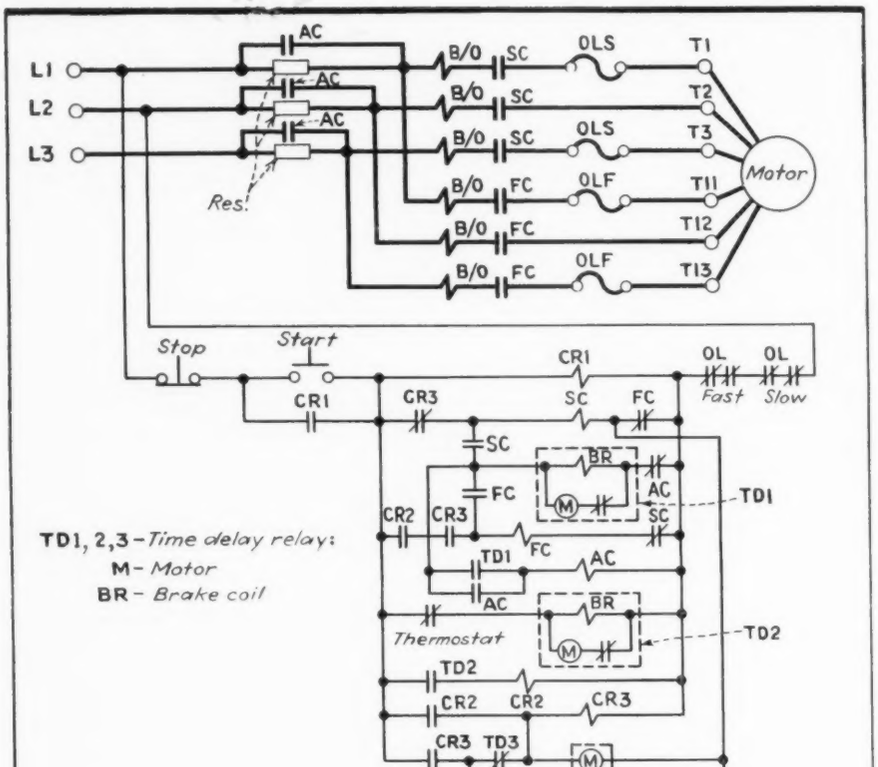


Fig. 4—Reduced voltage starting circuit for two speed motor drive.

loaded, relay *OL* 1 disconnects the motor from the line and motor No. 2 maintains the tank pressure.

Multispeed Drives

Fans, blowers and other equipment driven by multispeed a.c. induction motors often benefit from special controls. An airconditioning system, for example, uses an interesting magnetic controller with several special features as shown in Fig. 4 for controlling a two speed, two-winding 15/7.5 hp. induction motor driving a fan.

The primary resistor magnetic controller provides definite time acceleration, overload, and low voltage protection at both high and low motor speeds. In addition, compelled starting on slow speed from a remote start-stop pushbutton station, with automatic transition from slow to fast speed, and from fast to slow speed under thermostat control, is obtained. Starting inrush currents are limited to a predetermined value by the starting resistors. Other features include interlock protection, adjustable timing, and pilot circuit protection. Depressing the "Start" button closes the control relay, *CR* 1, and the slow contactor, *SC* connects the slow speed winding of the motor across the line in series with a single step of starting resistance. The control relay maintains itself and feeds the *SC* coil. An auxiliary contact on the "Slow" contactor energizes the first timing relay *TD* 1. At the end of its timing period, contact *TD* 1 closes, which closes accelerating contactor *AC*, thus shorting out the starting resistance and connecting the slow speed winding across the line.

The subsequent operation of the controller depends on the thermostat. If, at the time the "Start" button is closed the thermostat contacts are open then the motor will continue to run at slow speed. However, when the thermostat contacts close or if the thermostat contacts were closed at the time the "Start" button was depressed the second timing relay *TD* 2 is energized. At the end of its timing period *TD* 2 energizes control relay *CR* 2, which in turn energizes the second relay *CR* 3. The relay, *CR* 3, transfers the drive from slow to fast speed by de-energizing the slow contactor *SC* and completing the circuit to the "Fast" contactor coil *FC*. The "Fast" contactor connects the fast speed winding across the line in series with the starting resistor. Then the timing relay *TD* 1 and the accelerating contactor *AC* bring the motor up to full speed.

When the thermostat contacts open, *TD* 2, *CR* 2, *FC*, *TD* 1 and *AC* are de-energized in succession, disconnecting the motor from the line and allowing it to coast. The third timing relay, *TD* 3, is energized through the normally closed contacts of the control relay *CR* 2 and the fast contactor *FC*.

At the end of its timing period *TD* 3 de-energizes control relay *CR* 3, which through its normally closed contacts recloses the slow contactor *SC*, and the motor is accelerated to slow speed.

The setting of the timing relays to provide proper operation is an important factor in the operation of the controller. Timing relay *TD* 1 is set so the motor reaches approximately 90 percent full speed before the accelerating contactor *AC* 1 closes. Timing relay *TD* 2 is set for a delay of approximately 10 sec. longer than *TD* 1 to allow the motor to accelerate to slow speed before transferring to fast speed. To prevent excessive shock to the fan or motor, time delay relay *TD* 3 is adjusted to allow the motor to coast from high speed to approximately 80 percent of the full slow speed before transfer to the slow speed winding. Electrical cross interlocks, *FC* and *SC*, plus a mechanical interlock prevent the slow and fast contactors from being closed at the same time.

Precision and Safety

Machine tools probably require more special control considerations than any other single group of industrial drives. This is true of even relatively simple machine tools. For example, Fig. 5 shows the special control for an engine lathe driven by a 440 volt, two-winding, two-speed 25 hp. induction motor.

This reduced voltage type magnetic reversing controller provides two steps of acceleration in either direction of rotation, overload and low voltage protection on both high and low speeds. Automatic plugging, jogging of the motor in either direction, low voltage pilot circuit operation, and a safety feature that lets the lathe be turned by hand without starting the

motor, are included in the control.

Starting, reversing, stopping, and speed control is controlled by a two-speed reversing shipper rod master switch. Only one set of starting resistors is used since the motor current is the same in either direction or rotation. When the power is "on", the undervoltage relay *UV* remains closed until a power failure or low line voltage occurs, and the low speed contactor *L* connects the low speed winding to the starting resistors.

On moving the master switch to position No. 1 *FOR*: (1) The forward line contactor *FOR* closes connecting the motor to the line in series with the starting resistors; (2) as the motor accelerates, the centrifugal plugging switch *FOR* closes energizing control relay *WR* 2, allowing the first accelerating contactor 1*A* to close short circuiting the first step of starting resistance; (3) the plugging relay delays the operation of 1*A* until the motor accelerates sufficiently to close the relay; (4) time relay *TR* 1 begins its timing cycle and after several seconds energizes control relay *CR* 1; (5) this energizes the second accelerating contactor, 2*A*, short circuiting the remaining starting resistance and connecting the motor directly across the line.

For high speed, moving the master switch to the second *FOR* position energizes control relay *R* and releases the low speed contactor, *LO*. The low speed contactor auxiliary contacts *L* close and energize the high speed contactor *H* completing the connections for high speed operation. For the reverse direction, the operating sequence is similar.

To jog or inch the motor the *JOG FOR* or *JOG REV* pushbutton is pressed. Automatic starting is prevented when jogging in either direction by the opening of the normally closed pushbutton contacts that de-energizes the undervoltage relay *UV*.

The centrifugal plugging relay, belt driven from the motor shaft, has two functions: (1) To let the lathe be turned by hand for restocking or retooling, without danger of the motor starting suddenly and injuring the operator; and (2) to bring the motor to a quick stop when the master switch is moved to the "off" position. On plugging, the master switch is moved from position Nos. 1 or 2 *FOR* to the "Off" position, the for-

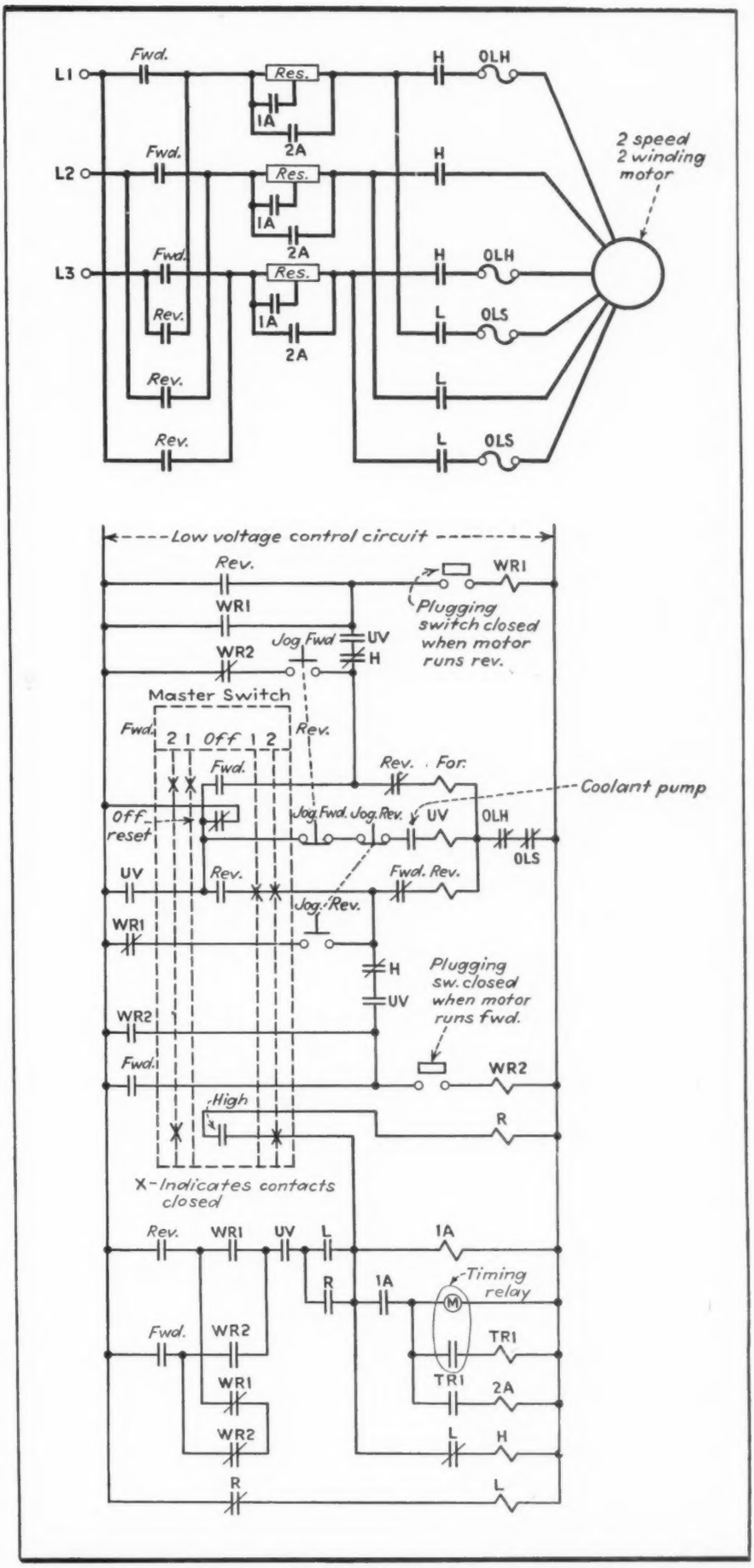


Fig. 5—Engine lathe reversing control provides automatic plugging and jogging.

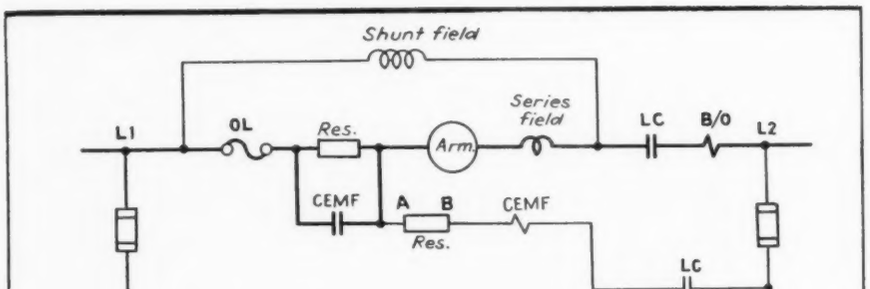


Fig. 6—Remote control circuit for operation of motor from two or more locations.

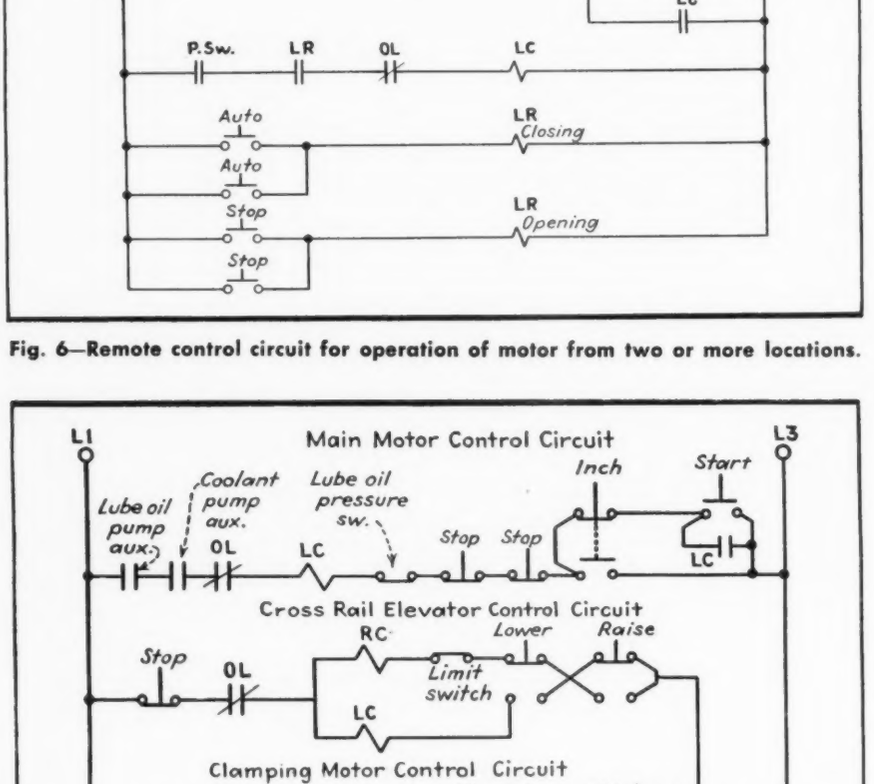


Fig. 7—Circuit for controlling 8 motors. Centralized, or grouped, control often simplifies operation and maintenance and saves space in industrial drives.

ward contactor opens and the reversing contactor *REV* closes reversing two phases to the motor. This reverses the motor but as zero speed is approached the plugging relay contacts *FOR* open *WR* 2, which deenergizes the reversing contactor. Similar operation takes place when the master switch is moved from position Nos. 1 or 2 *REV* to the "Off" position.

Mechanical and electrical interlocks prevent both speed contactors or directional contactors from being closed at the same time causing damage to the motor or the controller.

Remote Control

Remote control from two or more control locations of a.c. or d.c. motors with a low or under voltage release often requires special control schemes. Typical applications include motor operated lubricating, coolant priming, and other vital auxiliaries that must restart immediately after a power failure.

For example, in the priming pump control in Fig. 6 the circuit provides: (1) Low or under voltage release, (2) *CEMF* acceleration and overload protection, (3) motor operation from two remote pushbutton stations, and (4) automatic operation after the *AUTO* button is depressed.

When pushbutton *AUTO* 1 or *AUTO* 2 is momentarily depressed, if the pressure switch *PWS* is closed, the latching relay, *LR*, closes energizing the line contactor provided a mechanical latch holds the latching relay *LR* closed. After the motor accelerates to approximately 70 percent full speed, counter-emf contactor, *CEMF*, closes and connects the motor across the line. The motor is then automatically controlled by the pressure switch *PWS*.

Depressing either remote stop pushbutton energizes the opening coil of the latching relay that trips the mechanical latch and opens contact *LR* and thereby disconnects the motor.

Centralized Control

Centralized control often is advantageous since operation of all motors can be controlled by one operator. On many machines, grouped controls save space and simplify maintenance procedure and trouble shooting. Typical applications include

industrial machinery, engine room auxiliaries, and air conditioning systems. The circuit shown in Fig. 7 for controlling eight motors on a boring mill is a good example. The main motor drives the work while the three traverse motors and the cross rail elevator motor raise or lower the tools, or run them in or out. Other small motors are used for clamping, lubricating and cooling purposes. Two pendant type push button stations control all operations. Before the main motor can operate the lubricating oil and coolant pump interlocks, the overload contacts and the lube oil pressure switch must be closed. The main motor can be moved slightly by momentarily pressing the "Inch" push button that controls the line contactor. Pressing the "Start" button energizes the line contactor, which is held closed by its auxiliary contact *LC*.

The right, left, and side head motor controllers are suitable for jogging service only. Pressing the "Down-In" or "Up-Out" push buttons operates the motor in the proper direction. Limit switches limit the travel of the vertical or horizontal cutting tools. The cross rail elevator motor is controlled by the "Raise" or "Lower" push buttons and travel is limited by limit switch *LSW* 2. The clamp limit switches in the cross rail elevator control circuit prevent elevator operation unless the clamp limit switch is already in the clamp position.

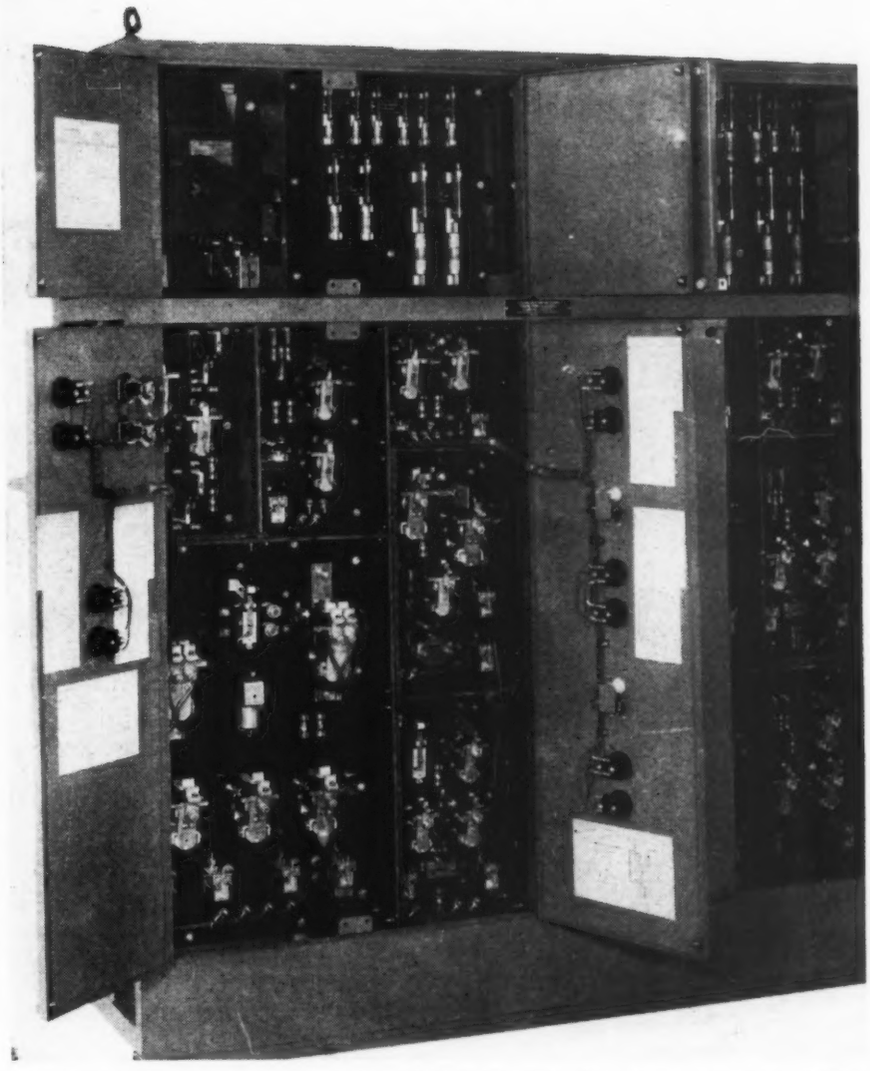


Fig. 8—Arrangement of grouped control with swinging doors for accessibility.

German Semi-Transparent Mirrors

SEMI-TRANSPARENT MIRRORS that absorb only one to two percent of the incident light and transmit light without coloring it perceptibly were manufactured in Germany during the war according to a report of the Office of Technical Services, Department of Commerce.

The report, prepared by Capt. John R. Whipple for the Combined Intelligence Objectives Sub-Committee, describes visits to the W. C. Heraeus Company at Hanau, Steinheil Sonne at Munich, and Siemens Schuckert Works at Berlin to obtain data on German vacuum evaporation methods for producing first surface mirrors, semi-transparent mirrors, and non-reflecting films. Steinheil Sonne manufactured semi-transparent mirrors that were resistant to water and abrasion and did not corrode in air. The "Steinheil-2" type mirrors consisting of a film of titanium dioxide on a glass base had a coefficient of light absorption of about one percent. The maximum reflectivity attainable in these mirrors reached 42 percent. Light passing through them acquired a barely perceptible pink tint.

The Horaeus company used vacuum evaporation methods that produced first surface rhodium-coated mirrors capable of reflecting 10 to 13 percent more light than similar mirrors made in the United States by electrolytic deposition. The Horaeus mirrors had a maximum reflectivity of 85 percent and the American mirrors, 72 to 75 percent. The report attributed the superiority of the German mirrors to the fact that vaporized or gaseous rhodium is purer than electrolytic rhodium. Special appendixes describe both coating methods.

Orders for the report (PB-4158, "German Vacuum Evaporation Methods", photostat, $3; microfilm, 50 cents) should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order, payable to the Treasurer of the United States.

Progress IN REVIEW

PLASTICS

Plastic materials in many forms; molded, high and low pressure laminated, foamed and in paints, are being used in many standard refrigerator parts. The trend points to an even greater use of plastics in future refrigerators and air-conditioning units. As reviewed in *Refrigeration Engineering*, June 1947, and *Modern Plastics*, June 1947, plastics are natural materials for making units that require temperature and electrical insulation properties. The plastics have eye-appeal that will help to sell the finished products and are easily fabricated. An experimental refrigerator has been manufactured in Australia. The cabinet was made of laminated plastic material and many of the internal components were constructed of plastics. There are some disadvantages inherent in plastics. They have a high thermal coefficient of expansion, and insulation foams have a high water absorption rate.

Wood-flour filled phenolic moldings have been subjected to accelerated shrinkage tests. Considerable range existed between the molding powders sold by various suppliers, as shown by a report in the May 1947 issue of *British Plastics*. Electronic or oven preheating reduced the amount of shrinkage in all specimens. After 30 days at 110 deg. C., the best material showed 0.6 percent linear or about 2 percent volumetric contraction; the worst indicated 1.3 percent linear or about 4 percent volumetric shrinkage.

Machine designers and manufacturers are beginning to catch up with the demand for special machines adapted for use with plastics. The operation of an automatic box-making machine is vividly portrayed in the June 1947 issue of *Modern Plastics*. Starting with a roll of transparent thermoplastic sheet, the machine cuts-off, blanks, folds and seals the joints. The plastic pieces are held by 9 rubber vacuum cups mounted on wooden blocks. The blocks are moved from station to station by a system of chains. Boxes, square or rectangular, up to 13 in. on a side and 4 in. in depth, can be made at the rate of 1,000 per hour from sheet stock 0.005 to 0.020 in. in thickness. Cellulose acetate is the only material that has been used but other types of thermoplastic materials should prove satisfactory. The seams are sealed by a solvent softening method, and each plastic would have to be sealed with an effective solvent.

Polyvinylacetate molding powder has counteracted one of the largest problems in the use of powdered metals. Powdered metals did not flow well in dies, which often resulted in porosity in some sections. Addition of 5 percent by volume of 200 mesh plastic powder improved the flow and reduced the amount of porosity. The resin can be completely burned out at low temperature, the piece de-gassed and recompacted in a 3 min. time cycle. An article in the June 1947 issue of *Modern Plastics* indicates that many uses have already been found for this process. It is especially useful in the preparation of carbide metal cutting tools, corrosion resistant alloys of high density and self-oiling bearings.

Compound forming of acrylic sheets has been accelerated with the development of a ridge-forming process. The new technique, a combination of the previous free-blowing and ring-forming processes, makes possible finished parts with greater depths of draw and with more uniform thicknesses. As illustrated in *Plastics*, June 1947, parts with a depth-to-diameter ratio of 1½ to 1 can be produced. Perfect optical properties can be retained if this process is carried out carefully.

Greater molding speed is possible, when using bulky, thermosetting molding powders, through the use of a new automatic preform press. Materials with compression ratios as high as 12 to 1, as mentioned in the June 1947 issue of *Modern Plastics*, can be automatically preformed. The machine can produce up to 20 tablets per minute with less than 5 percent weight variation at a pressure up to 75 tons. The machine was designed for use with high impact grade molding powders and asbestos brake lining materials.

A phenolic molded table top, to be used for general purposes, has been made in a single cavity die. The 12 lb. molding is said to be stronger than laminates of paper or wood, as light as any material of equivalent size and strength, and 20 percent lower in cost. According to an article in *Modern Plastics*, June 1947, the top is perfectly smooth and flat.

Formed acrylic fixtures for kitchens and bathrooms are being produced in England to ease the current metal shortage. Since the formed acrylics require little finishing, much time is saved over the slow process of vitreous enameling metal parts. Formed acrylics are inexpensive, according to *Modern Plastics*, June 1947, because only 30 lb. per sq. in. pressures are needed.

Preforming characteristics of general purpose, medium impact and high impact molding powders have been studied on presses of three types: mechanical; hydraulic, no dwell; and hydraulic, 1 min. dwell. It is indicated, in the June 1947 issue of *Plastics*, that there is an optimum pressure for each type of molding powder. Pressures higher than the optimum do not produce better density, but do increase wear on the mold.

Solvent and non-solvent plasticizers were thoroughly investigated to determine what processing improvements they would impart to synthetic rubbers. It was found that solvent-type plasticizers added no improvements; but smooth processing stocks were produced when non-solvent plasticizers were used. However, to prevent exudation and to maintain cohesive strength, the latter can be used only in limited amounts. According to a review in the

May 1947 issue of *Rubber Age,* experiments with GR-S, neoprene, acrylonitrile and butyl rubbers gave results that agreed with this theory. Silicone oils, which are not compatible with rubber, were used as lubricants and plasticizers. The results, improved extrudability and abrasion resistance, gave further proof to this idea.

Isoprene-styrene copolymers, in formulas similar to those of butadiene-styrene, have been found to show good properties in certain applications. As mentioned in *Rubber Age,* May 1947, these synthetics make tires with good blowout time, running temperature and ball rebound values. Another special synthetic, silicone elastomer, has been shown to be very stable. It is stable at high and low temperatures, under extreme weathering conditions and against exposure to oils and chemicals. This type of synthetic rubber has high tensile strength, elongation, hardness and flexibility physical properties.

Neoprene latex was substituted for natural rubber latex, during the war, without regard for the special properties of neoprene. The superior aging, solvent resistance and resistance to gas leakage properties are now being used properly. According to the May 1947 issue of *Rubber Age,* the good qualities of neoprene are being used in the production of dipped goods, extruded thread, balloons and foamed articles. Special formulations are also used in paper and fiber impregnation and in the manufacture of adhesives.

NONFERROUS METALS

The American aluminum industry may not be completely dependent on foreign bauxite as a source of raw material because of recent developments at the U. S. Bureau of Mines. According to Dr. R. R. Sayers, Bureau Director, investigations have indicated that about 86 to 89 perecent of the aluminum present in South Carolina kaolin, porcelain clay, can be recovered at a cost of approximately 50 dollars, per ton of calcined alumina. The lime soda sinter process is used in the recovery. Ore bodies of 10,000,000 tons of more than 33 percent alumina have been proved in Aiken County, S. C., and the *Daily Metal Reporter,* June 6, 1947, indicates that 9,000,000 tons of low grade are in known deposits.

Joining of light metals without the use of rivets or welding is now possible with the recently developed Redux Process. As mentioned in the May 1947 issue of *Light Metals,* the process has been used in England on such parts as sink and drain boards, fuselages, wings and other airplane parts, windows, furniture and bicycle frames. Spot welding fails to work well with metals of dissimilar thickness while gas or arc welding leads to warping of thin parts, requires cleaning, and even then may fail because of corrosion. In the Redux Process, the parts are cleaned with steel wool, or a chemical dip, coated with Redux liquid resin, clamped together and heated to 140-190 deg. C. for cure. Joints of this type have been found to be structurally sound and water proof.

Heat-treated aluminum alloy castings have high dimensional stability when they are chilled to —150 deg. Fahrenheit. Hydraulic valves for aircraft, without the chilling treatment, frequently tore during drilling and tapping operations, and exhibited excessive distortion following general machining operations. Parts chilled to —150 deg. F. prior to machining, as reported by A. C. Jones in the May 1947 issue of *Metal Progress,* could be held to the original dimensions after machining and could be drilled and tapped without tearing.

Finishes for nonferrous parts on installations involving high humidity and temperature are being continually investigated. Anodizing affords ample protection to wrought aluminum alloys, but it has been found that this protection will not prevent pinhole attack on aluminum alloy castings unless used in conjunction with a paint film. As pointed out by C. D. Cook and C. Merritt, Jr., *Materials and Methods,* May 1947, a nickel or tin plate of 0.0005 in. gives ample protection to brass, but tin is more liable to mechanical damage in service. Exposed to humidity alone, the silicon bronzes and beryllium copper alloys were found to require no protection, but when salt spray was present, a thin nickel plate was necessary. No satisfactory finish for zinc base die-castings were found by the authors, although fair protection was afforded by a chromate dip followed by a baked primer and a baked top coat. A chromatic treatment for magnesium alloys is satisfactory except when used with dissimilar metals.

Spinning aluminum provides designers with a process producing shapes with simple flowing contours. Aluminum and its alloys can be spun cold, and, as mentioned in *Modern Metals,* June 1947, can be spun to greater depth than any other material. Aluminum can be spun by hand, automatically or by a combined method. The greatest amount of spinning at room temperature is performed on metal not more than 3/16 in. thick. Aluminum sheets up to 3/8 in. are usually spun heated to 400 deg. F. before being worked. Blanks of thin aluminum are lubricated with beeswax, tallow or petroleum jelly, while yellow laundry soap is used to lessen the friction and to prevent marring thicker blanks. Spinning is done with lathe speeds from 250 to 1,140 rev. per minute.

Small metal parts can be centrifugally cast with very high purity in a vacuum. The equipment, according to J. D. Nesbit, *Iron Age,* June 19, 1947, has worked at 0.000 005 of atmospheric pressure, 3 to 4 microns. The metal can be melted, alloying elements can be added, and deoxidation and pouring steps can be taken without breaking the vacuum. A 1 hr. cycle is possible when using a pressure of 50 microns. Mechanical pumps are used to get the vacuum down to 100 to 1,000 microns and oil diffusion pumps are used below the limit for the mechanical pumps. The heat of the melting furnace is obtained from 440 volt current at either 960 or 10,000 cycles. Since the motor drive on the centrifugal casting machine is within the evacuated chamber, some gassing of the lubricating oil is apt to occur. Casting motor speeds can be 600, 1,200 or 2,400 rev. per minute. Several hundred types of alloys have been successfully melted and cast in equipment of this type.

Bonding aluminum to steel by the Al-Fin process has made available another bimetal for such applications as cylinder and compressor barrels, heat exchanges and finned assemblies where the strength of steel or cast iron and the corrosion resistance of aluminum are desired. In addition to 2S, as reported in the March 1947 issue of *Modern Metals,* the common aluminum alloys: 43, 195, 356, 142, 355 and C13 have been bonded to cast iron. No unusual foundry equipment is needed when using this process.

Powdered metals will become more advantageous in industrial uses with the further development of pre-cast powder and hot pressing techniques. Pre-cast powders can extend the field of powder metallurgy to alloys not formerly available. Nickel silver powder can be made by preparing the alloy using conventional melting practices, and crushing the solidified casting into a powder of the alloy. As shown by G. J. Comstock and J. D. Shaw, *Iron Age, May* 22, 1947, any alloy that can be prepared by melting can also be made available as a powder. The hot pressing technique permits the manufacture of powder metal parts at lower pressures than

those used in cold pressing. The primary metal powders were very soft and workable, and could be pressed into shape with relative ease. The alloys can only be worked at high pressures, if normal densities are to be produced. The hot pressing process will give high strength, high density materials suitable for many applications now beyond the scope of powder metal products.

IRON AND STEEL

Rough surfaces on iron castings need be tolerated no longer. The grains of molding sand are coated with a plastic film that burns as the molten metal is poured into the mold. As mentioned by W. G. Gude in the May 1947 issue of *Foundry*, it is presumed that a thin blanket of gaseous products of combustion prevents contact between the metal and the sand until a frozen skin has formed on the metal surface. Burning-in of sand particles is prevented by this skin. This technique is similar in effect to the rubber-bonded cores and molds reported by the Bureau of Standards some years ago. Some large foundries are converting to the use of plastic-coated sands.

Sandwich materials, made with thin galvanized steel sheets bonded to plywood or a similar filler, are being used in many ways by designers. They are being used more extensively because they have good stiffness in the finished form and because they are easily machined. A staff article in *Steel*, June 9, 1947, shows numerous design applications and illustrates the ease of fabricating with sandwich materials.

Flux-injection cutting of stainless steels is now as easy as regular flame cutting of mild steels. Since stainless steel alloys are high priced materials, every cost factor affecting the transformation from stock to finished product is important. For the 35 years since its development, users of stainless have had to rely on melting cuts or machining methods to shape these alloys. The flux-injection cutting process chemically removes obstructing oxides. Finely pulverized flux is injected directly into the cutting-oxygen stream prior to its entry into the torch. The flux and the oxygen strike the stainless steel simultaneously at the point of the cut. When the oxygen burns away a layer of steel, the flux removes the resultant oxides. Fresh base metal is always exposed to the cutting jet. This method of cutting can be done with any standard flame-cutting machine that carries a 3-hose torch fitted with heavy preheat tips. The flux-feeding unit is the only special piece of equipment necessary. Carbide precipitation may reduce the corrosion resisting property of the cut stainless steel. This problem, as mentioned by G. E. Bellew, *Steel*, Feb. 17 and 24, 1947, is common to all methods of heat-working stainless steels. Carbon precipitation in stainless steel occurs in the temperature range from 800 to 1,600 deg. F., particularly when held around 1,400 deg. F. for some time. In this temperature zone, chromium and carbon have an affinity and tend to precipitate at the grain boundaries as chromium carbides. This tendency to precipitate can be counteracted by the methods used with other processes that heat the stainless alloys. The best preventative solution to the precipitation problem is the use of titanium or columbium to stabilize the steel. These two elements have a greater affinity for carbon than does chromium, and they form harmless carbides. The chromium is unaltered and maintains the corrosion resistance of the stainless steel.

Precision castings are being specified in ever increasing numbers by design engineers. Precision casting methods include the recently revived lost wax process, die-casting, permanent mold casting and plaster mold casting. As discussed by G. Vennerholm and E. Ensign in the June 1947 issue of the *SAE Journal*, all precision casting methods minimize the amount of machining necessary by providing castings with accurate dimensions. One or another of these methods can be used for practically all the alloys now in use.

Iron castings, defective as poured or broken in service, can be salvaged. They can be arc welded, according to D. W. De Armand and S. Epstein, *Foundry*, May 1947, if a coated nickel-base welding rod is used. The weld area formed is strong and can be machined.

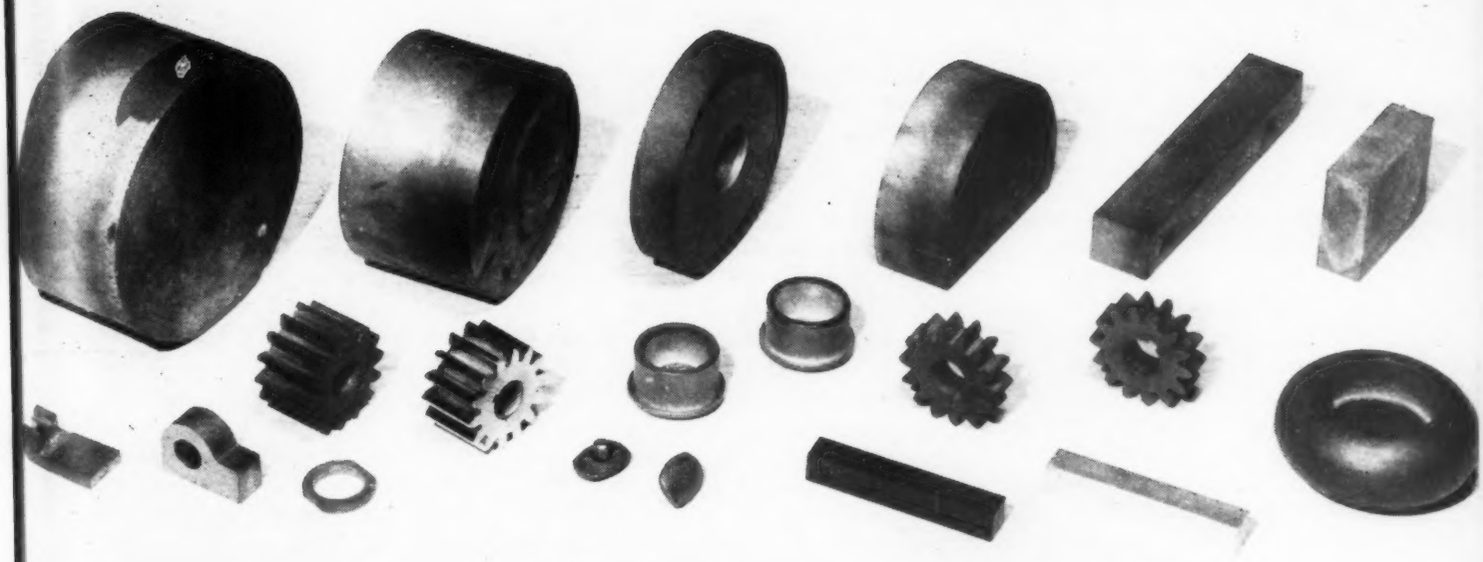
Steel wool bushings have been made to give excellent service with a high degree of porosity that retains lubricant. The steel wool was compressed and impregnated with copper by a copper-brazing process. In aircraft gears, as mentioned by C. O. Herb, *Machinery*, June 1947, the bushings are copper brazed to the tubing while it is in place. The bushings are integrally bonded to the gears in one operation.

Malleable iron castings are very dependable when the design specifications are understood by the foundry. Where the foundry is an integral part of the firm manufacturing the finished products, the specifications are understood and the limitations are discussed before the design is frozen. It has been mentioned by J. E. Linabury, *Foundry*, June 1947, that the same amount of understanding must be in evidence when castings are purchased from an outside foundry. It is good practice to include with the specification sheet a clear statement of the conditions of use for the final product. In this statement, the designer should make it perfectly clear which of the properties are really important and which are not. The foundry can adjust the pouring of the metal to give the necessary properties when the service of the part is known.

Four carburizing steels have been developed to meet the need for deep hardening steels that can be easily processed and machined into airplane, truck, bus and other gears, shafts and pinions. The new steels are designed to cut material and manufacturing costs in products subject to heavy duty service. Costs have been reduced by making effective use of the alloying elements, and these steels show hardenability equal to or greater than the more highly alloyed grades now used. With this refinement, these steels have not lost the high core strength and the toughness needed for heavy-duty applications.

Shot-peened rear axle shafts are said to double the fatigue life of ordinary shafts now used on trucks. In the process of shot-peening, axle shafts are bombarded with thousands of small, steel shot. Each shot makes a slight indentation in the surface of the metal. This causes a slight but permanent stretching of the metal, both on the surface and also to a slight depth below the surface. The surface zone of metal is strengthened by changing the shape and orientation of the grains of metal. The strengthened surface resists fractures. Shot-peening removes scale caused by forging and heat-treatment and thereby increases the resistance of the surface to cracks. This process increases the surface hardness of the axle and increases its resistance to wear. The proper amount of shot-peening will strengthen a part; too much will weaken it.

Steam drop hammers are preferred to board drop hammers for many industrial uses. In certain operations the higher speed and controlled blow of the steam-type are desirable. In addition to lifting the ram, steam is also used to drive the ram downward. One manufacturer of steam drop hammers is now using heavy steel plates instead of castings to form the anvils. Six plates are flame-cut to size and tied together by heavy alloy steel tie-bars that are shrunk in place.



Billets and a variety of parts made by alloying powdered iron compacts with copper.

Improved Engineering Properties Of Parts Made From Iron Powders

CLAUS G. GOETZEL
Technical Director, American Electro Metal Corporation

MARKED improvement in the physical properties of parts made from iron powder has resulted from the technique of filling the pores to reduce porosity rather than from the application of high pressures to condense the compact. The physical properties are closely related to the density obtainable in the sintered products. It is generally accepted that the inherent porosity is the main cause for the deficiency in certain physical characteristics, particularly ductility and impact strength. All attempts to improve the physical properties of sintered iron parts therefore have been directed mainly towards a reduction of residual porosity.

Single Pressing and Sintering

When work was started on iron powder metallurgy some 15 or 20 years ago, the presses and equipment available limited the molding pressures and the sintering cycles that could be used. Consequently the iron products had only moderate physical properties. The densities of such parts were in the order of 75 percent of normal when a pressure in the order of 30 tons per sq. in. was applied.

Only high temperature sintering was found in later years to result in high densities within the part. Furthermore, this meant considerable shrinkage during sintering which, of course, meant less exact configuration of the parts. This was undesirable because the manufacture of iron base products depends essentially upon the production of parts of precise configurations and of accurate size.

The tensile properties obtained with such porous material were low in comparison to bulk iron, such as Armco iron, the tensile strength never exceeding about 25,000 lb. per sq. in. and the elongation not exceeding 10 or 15 percent. The next thought was to increase the pressures and increase the time of sintering and other processing operations. By approximately doubling the pressure, in other words, raising it to about 60 tons per sq. in., the tensile strength could be increased at least 50 percent and, provided a suitable iron powder was used, a single compression and a sintering at 1,200 deg. C. for two or three hours resulted in tensile strengths of the order of 30,000 lb. per sq. in.; elongation values of the order of 15 to 20 percent; and Izod impact strength values of the order of 6 to 8 ft.-lb. With that procedure the limit had been reached in the feasible commercial operations.

There existed definitely a demand to improve these physical properties. A study revealed that nothing was gained by raising the pressure from 60 to 100 tons per sq. in. because the compacts were work-hardened so much at about 85 percent of normal metal density that additional pressure without releasing the work-hardening effects was ineffective. To include in the operation an intermediate annealing or sintering step

was necessary, and this had to be followed by a second pressing operation, which is generally referred to as cold coining.

Re-pressing and Re-sintering

By this method of twice pressing and twice sintering the pure iron powders, tensile strength values in the order of 35,000 to 40,000 lb. per sq. in. could be obtained, with elongation values somewhere between 20 and 30 percent, depending upon the purity of the powder, the time of sintering, the purity of the sintering atmosphere, and the coining pressure.

This approach was the culmination of the efforts to mold directly pure iron products to concise shape. Since their physical properties were still considerably inferior to those from fused electrolytic iron, or to those from low carbon steels, it was thought to improve them further by giving the metal a drastic metal working operation, either by cold working, such as cold rolling or cold hammering, or by hot working, such as hot forging. The following physical properties were then obtained: Tensile strength values up to 60,000 lb. per sq. in.; retention of the elongation values of 20 to 30 percent and the 15 ft.-lb. Izod impact values.

One great disadvantage of this method was seen in the fact that the most important criterion of the powder metallurgy process was lost. The plastic deformation of the material, and further sizing or fabricating to exact shape invariably meant machining or stamping operations that made the entire process unattractive from a commercial point of view.

Hot Pressing and Alloying

Attempts were then made to retain the advantages of the hot working and the basic axiom of molding to precise shapes by combining the operation into a hot pressing or a hot coining operation. Laboratory experiments showed very encouraging results, tensile strengths of pure iron going up to about 60,000 lb. per sq. in., elongations up to 35 percent, and Izod impact strengths in the 15-ft.-lb. range.

But lack of proper die materials, the comparatively slow work cycle of the process, the necessity of protecting the compacts by protective atmosphere, and the general lack of know-how by people who produce processing equipment in powder metallurgy so far has prevented bringing onto the market a commercially sound hot-pressing machine of satisfactory productive capacity. Neither the press manufacturers nor the furnace manufacturers have dared to build something that is not salable to everybody in the field. So hot pressing or hot coining has stayed essentially in the laboratory, and with the exception of a few noteworthy attempts to hot coin some parts for the automotive indusry, there has been reported no marked advance in this direction.

The next step was the attempt to improve physical properties by alloying. The results with carbon steel products are quite encouraging if the right technique is used. Particularly, where a few tenths of one percent of carbon only are added, a marked increase in strength over plain iron products can be obtained. At the same time, ductility values remain fairly constant and in the same order as those for plain iron.

For example, for a low carbon steel containing 0.27 carbon, if pressed, sintered, re-pressed and re-sintered to a final density in the order of 90 percent of the theoretical, tensile strength values of 56,000 lb. per sq. in. and elongation values of 23 percent were recorded. When the carbon was increased to a carbon content of about 0.87 percent, a eutectoid structure was developed, the density was retained, the tensile strength was raised to about 85,000 lb. per sq. in., and the elongation reduced to about 7 percent.

These materials had the added advantage that they were subject to heat-treatment. For the 0.27 carbon steel, after heat-treatment, a tensile strength of 66,000 lb. per sq. in. was recorded with an elongation of 13 percent. On the other hand, the high carbon of eutectoid steel composition displayed after heat treatment, tensile strengths up to 150,000 lb. per sq. in. with an elongation of 4 percent.

In summarizing, it can be said that in the low carbon ranges, that is from 0.25 to 0.5 percent C., the tensile strength, after heat treatment, reaches the lower brackets of the SAE steels of the same carbon content. Ductility values also are close to the lower limits of the SAE steels. While the SAE steels have about 30 percent elongation, the sintered steels reach values in the order of 20 to 25 percent. The reduction of area values, on the other hand, which are generally considered a better criterion of ductility than elongation, are lower so that the ratio of about 1½ to 1 between reduction of area and elongation, which is found in steels, cannot be expected of the sintered steels. In the high carbon steel materials, elongation and reduction of area values decrease to a few percent, indicating that the sintered metal is brittle.

Infiltration

After this field of alloying iron with carbon had been thoroughly investigated and its respective limitations had been fully recognized, attempts were made to approach the problem still from another angle. It was clearly recognized that the pores were mainly responsible for the shortcomings. What had been done so far was to try, either by additional energy input or by metallurgical and chemical manipulation, to overcome the handicap imposed by the pores.

In the former the aim was to condense the compacts mechanically by higher pressures or by re-pressing, coining and forging. In the latter the pores were disregarded altogether, the aim being to concentrate the strength into the metallic network.

Without exaggeration, it can be said today that the pores, so long as they comprise more than about 10 percent of the volume, are definitely harmful because the effects of them are similar to the effects of sharp corners in a designed part. Each pore acts as a stress raiser. With millions of pores in a compact and with the material subjected to a triaxial state of stress, the pores are known seriously to affect the ductility, and probably somewhat less seriously, to affect the strength. It was thought to simulate the approach that is used by designers in overcoming sharp corners in designs, namely to introduce fillets. By using metal to fill the pores, at least in part, the notch effect of each pore was relieved.

Obviously, the ideal way would have been to place iron into the pores

Table I—Physical Properties of Carbon-Free Cemented Electrolytic Iron

Ratio, Fe/Cu	Density, percent of theoretical	Yield point, lb. per sq. in.	Tensile strength, lb. per sq. in.	Elongation in 1 in., percent	Reduction in area, percent	Izod Impact, ft.-lb.	Brinell hardness
88/12	98.9	53,000	65,100	7.0	8.0	8	164
84/16	98.0	28,500	53,800	24.0	31.5	12	104
79/21	98.1	27,600	53,300	28.0	36.7	14	91
77/23	98.0	25,400	52,500	34.0	36.7	15	85
72/28	98.8	24,300	45,800	32.0	32.3	18	68

Table II—Conductivity of Cemented Iron and Steel from Electrolytic Iron Powder

Material	Volume ratio of iron to copper, percent	Density			Conductivity				
		g. per c.c., theoretical	g. per c.c., actual	Ratio of actual to theoretical, percent	1/microhm-cm theoretical	1/microhm-cm actual	Ratio of actual to theoretical, percent	Percent change over base metal	
								Iron	Pearlite
*Copper or Cu	.....	....	....	....	0.5820	.....	....	....	....
Iron or Fe	.....	....	....	....	0.1000	.....	....	....	....
0.75 C Pearlite	.....	....	....	....	0.0568	.....	....	....	....
Fe/Cu	55/45	8.40	7.94	94.6	0.3169	0.1062	33.45	6.2	....
Fe/Cu	65/35	8.24	8.10	98.5	0.2687	0.1125	41.8	12.5	....
Fe/Cu	70/30	8.19	7.84	96.8	0.2445	0.0986	40.3	−1.4	....
Fe/Cu	75/25	8.14	7.96	97.7	0.2205	0.0994	45.0	−0.6	....
Fe/Cu	80/20	8.08	7.80	96.6	0.1964	0.0949	48.3	−5.1	....
Pearlite/Cu	55/45	8.40	8.04	95.8	0.2930	0.0966	32.95	....	70.1
Pearlite/Cu	65/35	8.24	8.04	97.7	0.2406	0.0946	39.3	....	66.6
Pearlite/Cu	70/30	8.19	8.02	98.0	0.2143	0.0918	42.8	....	61.7
Pearlite/Cu	75/25	8.14	7.84	96.3	0.1881	0.0846	44.95	....	49.0
Pearlite/Cu	80/20	8.08	7.68	95.4	0.1619	0.0763	47.1	....	34.4
Effect of heat-treatment at 833 deg. C. followed by water quench									
Fe/Cu	75/25	8.14	7.82	96.1	0.2205	0.0711	32.2	−28.8	....
Effect of subsequent precipitation hardening at 500 deg. C. for one hour†									
Fe/Cu	75/25	8.14	7.82	96.1	0.2205	0.1167	52.8	16.7	....

* Oxygen free, high conductivity.

† Heat-treatment and quench reduce the conductivity of the infiltrated material by 28.1 percent while heat-treatment and quench followed by precipitation hardening result in an increase of 17.4 percent.

and thus form a uniform mass of iron. This being impossible, the next thing was to try a lower melting metal to infiltrate into the porous body, copper alloys being the natural choice.

Some interesting research had been done in this direction during the past thirty years and some of it was recorded, though surprisingly, not commercially exploited to date. It was observed that the copper in the liquid state penetrated into the pore volume and thereby constituted a filling mass. When this is done—the composite material consisting of an iron skeleton and copper filler—some amazing results are found. Table I contains some typical test data. First, the notch effects of the pores are greatly reduced, and the tensile strength and elongation are improved over those of the iron skeleton alone.

Second, and probably the more important, it was found that some degree of alloying takes place between the iron and the copper. The surface of the iron particles are partly dissolved by the copper. In other words, the infiltrant not only functions as a filler to remove sharp angles in the pores, but also functions as cement to strengthen the entire base structure in a process somewhat similar to the one known to take place in the sintering of cemented carbides.

As another indication of that definite degree of alloying that takes place, conductivity measurements were made. While the conductivity was somewhat lower than expected from the rule of mixtures because of the partial alloying, it could be further decreased by solution treatment, as shown in Table II. Precipitation treatment by heating at 500 deg. C. increased the conductivity to about 20 percent International Annealed Copper Standard. Thus, as a third interesting criterion, it was found that not only does partial alloying take place between the iron and the copper but also that a particular precipitation hardening takes place between them. By variations in subsequent heat treatments, an iron skeleton filled with copper can have a variety of physical properties, from a comparatively low tensile strength in the order of 55,000 to 60,000 lb. per sq. in. together with an elonga-

tion in the order of 30 percent, to a tensile strength in the order of 90,000 lb. per sq. in. and an elongation of 10 percent.

Finally, after this interesting development was fully recognized, the question came up as to whether the strength could be still further improved by alloying either the skeleton metal or the infiltrant. Both ways were tried, and the scope of the work being so tremendous, it can today only be reported that the initial results appear successful.

As a first important step, the skeleton material was alloyed with carbon, with the result that the presence of carbon changes the partial alloying between the copper and the iron materially and permits a new series of heat treatments similar to those for steel. This occurs in addition to the precipitation hardening between the iron and the copper. Table III gives some test results obtained by these treatments.

The tests extended both to iron and steels cemented by copper and to iron and steels, including stainless steel and other alloy steels, cemented by copper alloys containing ingredients such as tin and phosphorus, which strengthen the compacts still more. Tensile strength values considerably above 150,000 lb. per sq. in. have been recorded, with elongation in the order of 5 percent. Izod impact values up to 15 ft.-lb. have also been recorded in some of these materials. In addition, certain preliminary tests indicate that the physical properties can be considerably improved by coining as well as by the alloying procedure.

While hot working experiments, such as extrusion, with iron-copper composite materials generally have not been successful, in isolated instances satisfactory sections of bar stock have been produced. Such material was found to possess a tensile strength of 80,000 lb. per sq. in. with an elongation of 20 percent and a reduction of area of 27 percent. It is gratifying to say that the less expensive reduced iron powders gave apparently the better results.

The improvements achieved by the infiltration process over the other processing methods are apparent from the data compiled in Table IV. Figs. 1 and 2 illustrate some of the data by curves for more ready comparison.

Table III—Physical Properties of Cemented Steels from Electrolytic Iron

Steel, percent C	Copper, percent	Compacting pressure, tons per sq. in.	Heat-treatment (See Note)	Yield point, lb. per sq. in.	Tensile strength, lb. per sq. in.	Elongation, percent	Reduction in area, percent	Izod impact, ft. lb.
0.2	30	8	f.c.	80,000	92,000	5	5	5
0.2	30	8	w.q.t.		102,000			
0.2	25	10	f.c.	88,000	95,000	3		4
0.2	25	10	w.q.t.	99,000	104,000	2	0	
0.2	20	12	f.c.	94,000	96,000	3	2	3
0.2	20	12	w.q.t.	99,000	105,000	2		
0.4	30	8	f.c.	80,000	87,000	3	2	3
0.4	30	8	w.q.t.	97,000	104,000	3	2	
0.4	25	10	f.c.	82,000	89,000	3		2
0.4	25	10	w.q.t.	85,000	104,000	3	1	
0.4	20	12	f.c.	87,000	88,000	3	2	2
0.4	20	12	w.q.t.	103,000	107,000	3	2	
0.4	20	12	p.q.t.	97,000	120,000			
0.6	25	10	f.c.	46,000	77,000	4	4	3
0.6	25	10	o.q.t.	66,000	83,000	3	3	
0.6	20	12	f.c.	73,000	97,000	4	4	
0.6	20	12	o.q.t.	76,000	97,000			
0.6	15	20	f.c.	78,000	96,000	4	4	
0.6	15	20	o.q.t.	77,000	93,000	2	2	
0.6	10	50	f.c.	79,000	81,000	4	4	
0.6	10	50	o.q.t.	75,000	90,000	2	2	
0.6	10	50	w.q.t.	109,000	115,000			
1.1	25	10	f.c.	64,000	76,000	4	4	3
1.1	25	10	o.q.t.	78,000	87,000	2	2	
1.1	20	12	f.c.	81,000	98,000	4	4	
1.1	20	12	o.q.t.	79,000	106,000	2	2	
1.1	15	20	f.c.	78,000	96,000	2	2	
1.1	15	20	o.q.t.	84,000	100,000			
1.1	10	50	f.c.		80,000	1	1	
1.1	10	50	o.q.t.	80,000	87,000			
1.1	10	50	w.q.t.		104,000			

Note: f.c. = furnace cooled.
w.q.t. = furnace cooled, reheated, water-quenched, tempered.
o.q.t. = furnace cooled, reheated, oil-quenched, tempered.

Table IV—Comparative Data on Materials Made by Different Methods

Material	Yield point, lb. per sq. in.	Tensile strength, lb. per sq. in.	Elongation, percent	Reduction of area, percent	Izod impact, ft.-lb.
Cast Copper	.....	33,000	40	50	50
Copper powder pressed at 50 tons per sq. in. and sintered	.....	20,000	10	10	3
Copper powder twice pressed at 50 tons per sq. in. and sintered	.....	28,000	20	20	5
Electrolytic fused iron	20,000	40,000	50	70	30
Armco Iron	30,000	50,000	30	40	20
0.6 carbon steel	60,000	95,000	20	40	50
Iron powder pressed at 50 tons per sq. in. and sintered	21,300	34,000	15	18	5
Iron powder twice pressed at 50 tons per sq. in. and sintered	20,000	37,000	25	25	8
80/20 cemented iron	40,000	53,000	25	32	12
80/20 cemented 0.2 carbon steel, heat-treated (water quench)	100,000	114,000	3	2	.....
80/20 cemented 0.6 carbon steel, heat-treated (oil quench)	75,000	97,000	4	4	.....
80/20 cemented 1.1 carbon steel, heat-treated (oil quench)	80,000	102,000	2	2	.....

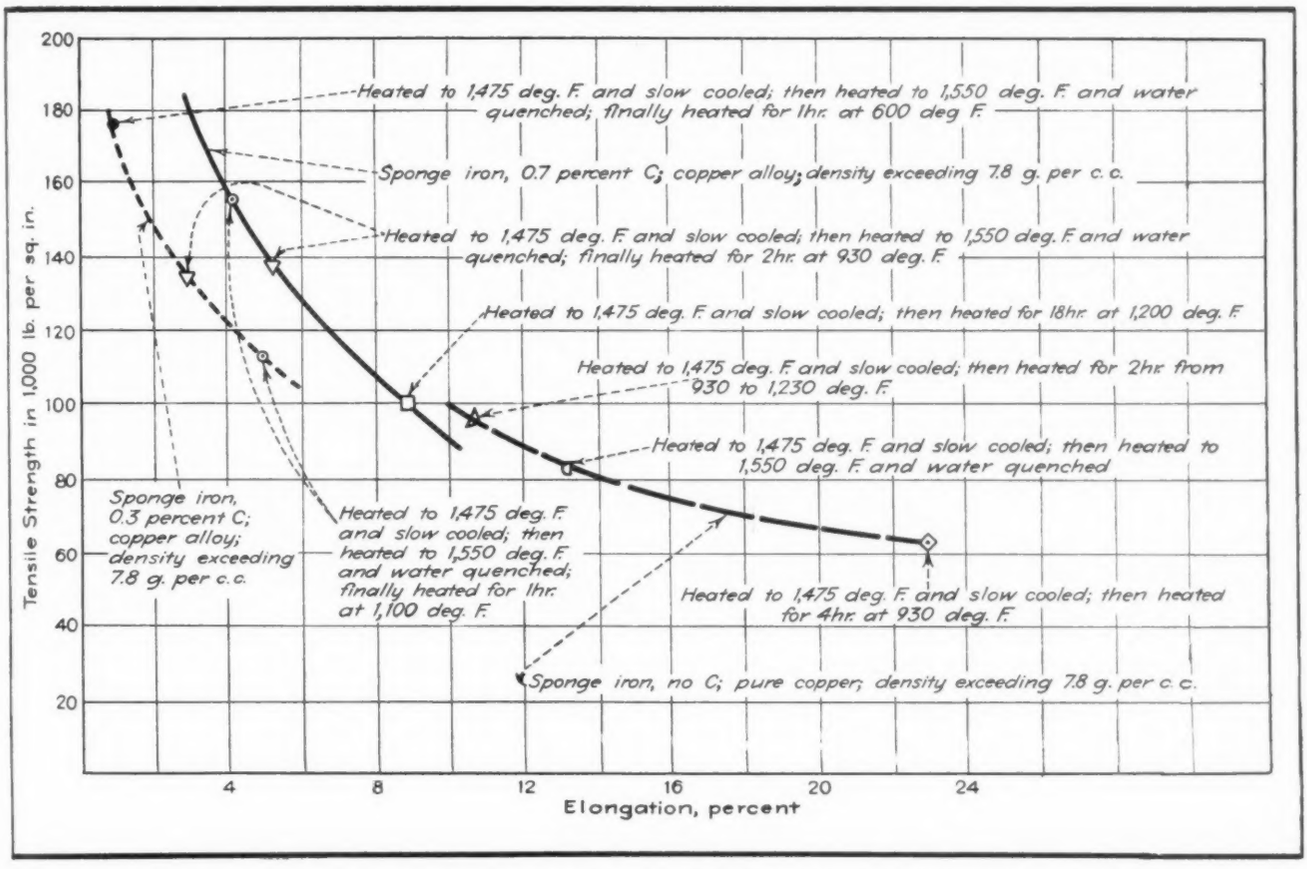

Tensile Strength in 1,000 lb. per sq. in.
200
180
160
140
120
100
80
60
40
20
4
8
12
16
20
24
Elongation, percent
Heated to 1,475 deg. F. and slow cooled; then heated to 1,550 deg. F. and water quenched; finally heated for 1hr. at 600 deg F.
Sponge iron, 0.7 percent C; copper alloy; density exceeding 7.8 g. per c. c.
Heated to 1,475 deg. F. and slow cooled; then heated to 1,550 deg. F. and water quenched; finally heated for 2hr. at 930 deg. F.
Heated to 1,475 deg. F. and slow cooled; then heated for 18hr. at 1,200 deg. F.
Heated to 1,475 deg. F. and slow cooled; then heated for 2hr. from 930 to 1,230 deg. F.
Heated to 1,475 deg. F. and slow cooled; then heated to 1,550 deg. F. and water quenched
Sponge iron, 0.3 percent C; copper alloy; density exceeding 7.8 g. per c.c.
Heated to 1,475 deg. F. and slow cooled; then heated to 1,550 deg. F. and water quenched; finally heated for 1hr. at 1,100 deg. F.
Heated to 1,475 deg. F. and slow cooled; then heated for 4hr. at 930 deg. F.
Sponge iron, no C; pure copper; density exceeding 7.8 g. per c. c.

Fig. 1—Curves showing effects of heat treatment on different types of iron powder products.

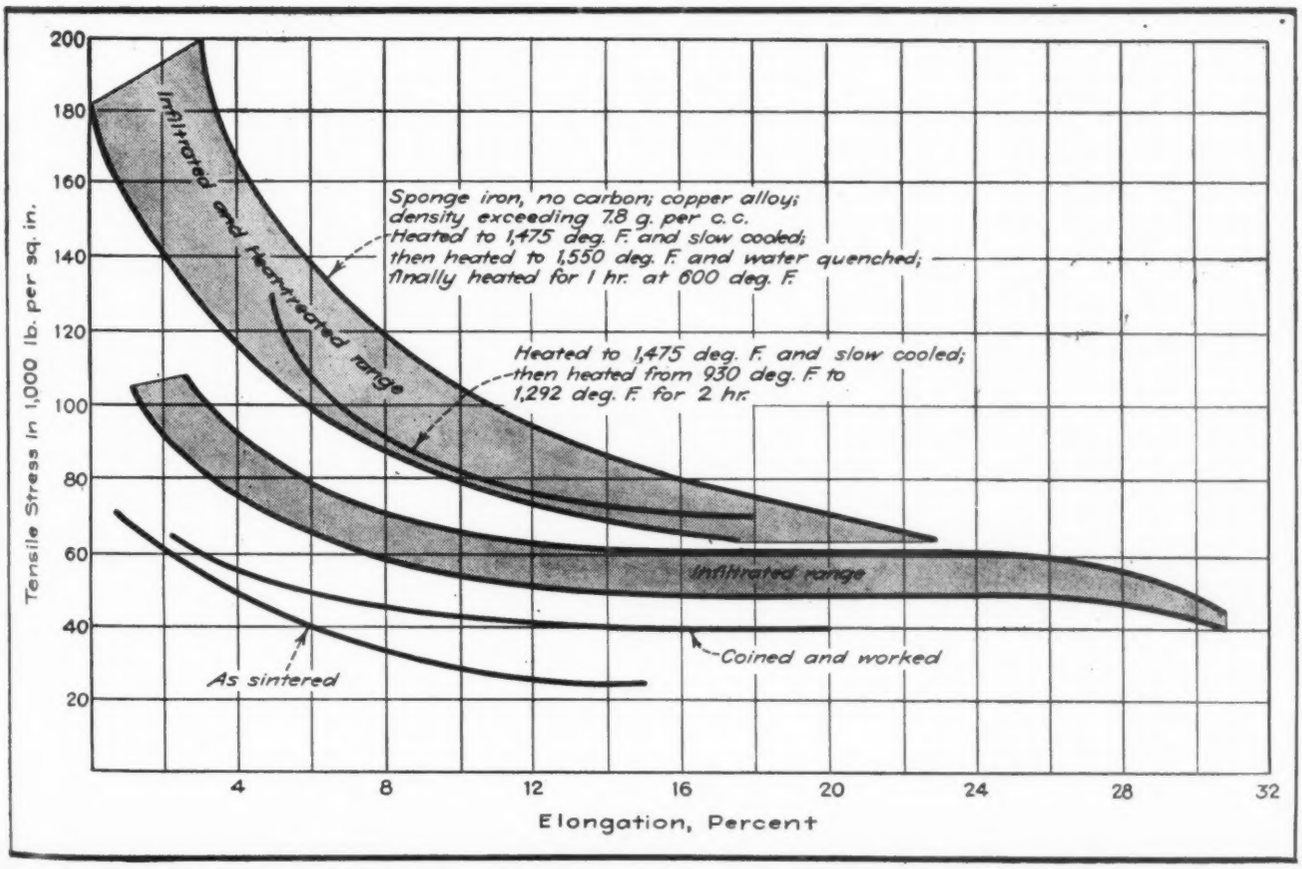
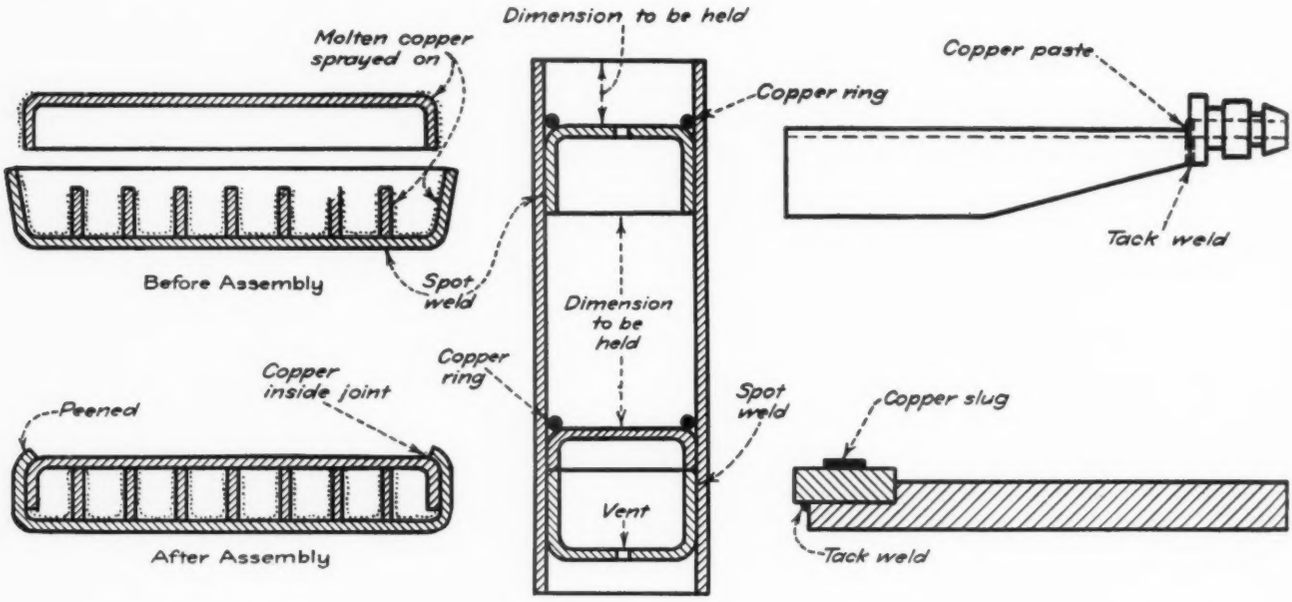


Fig. 2—Curves showing ranges of physical properties of iron powder products obtained by several methods of production.

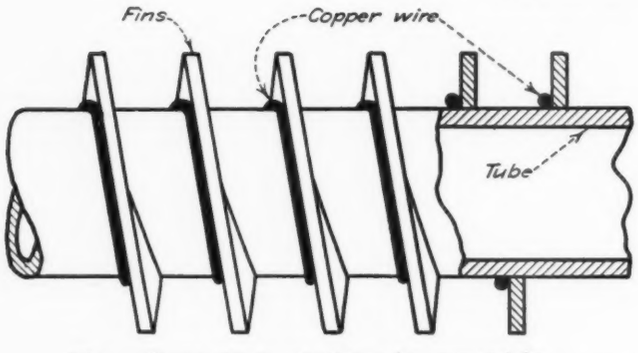
Methods for Maintaining Positions and

A series of sketches indicating various ways to hold the positions and dimensions of parts during the brazing process. Examples are shown of welding and assembly techniques, permanent and temporary methods of support and three instances of poor practice. Sketches courtesy the General Electric Company.

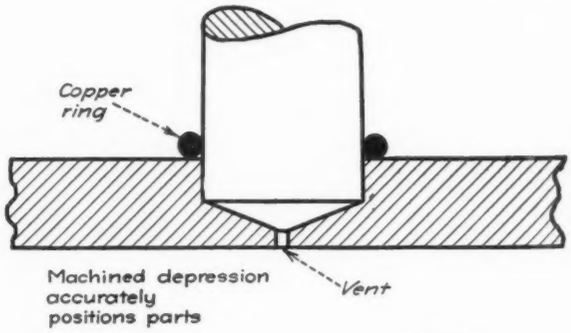
POSITIONS HELD BY SPOT AND TACK WELDING



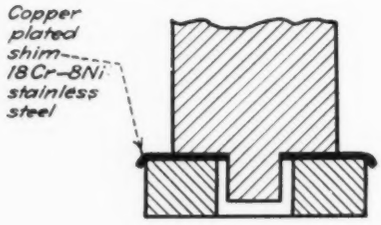
TYPE OF ASSEMBLY KEEPS POSITION



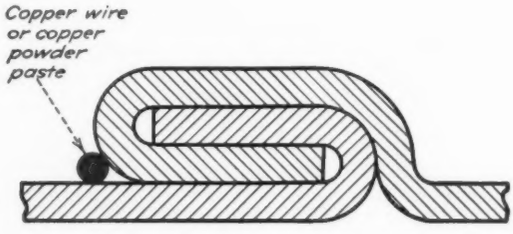
Fins will remain in position when wound in this manner, but are generally tack welded at ends



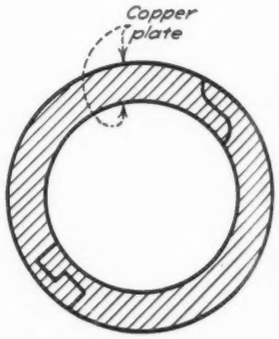
Machined depression accurately positions parts



Parts held in position by their own weight



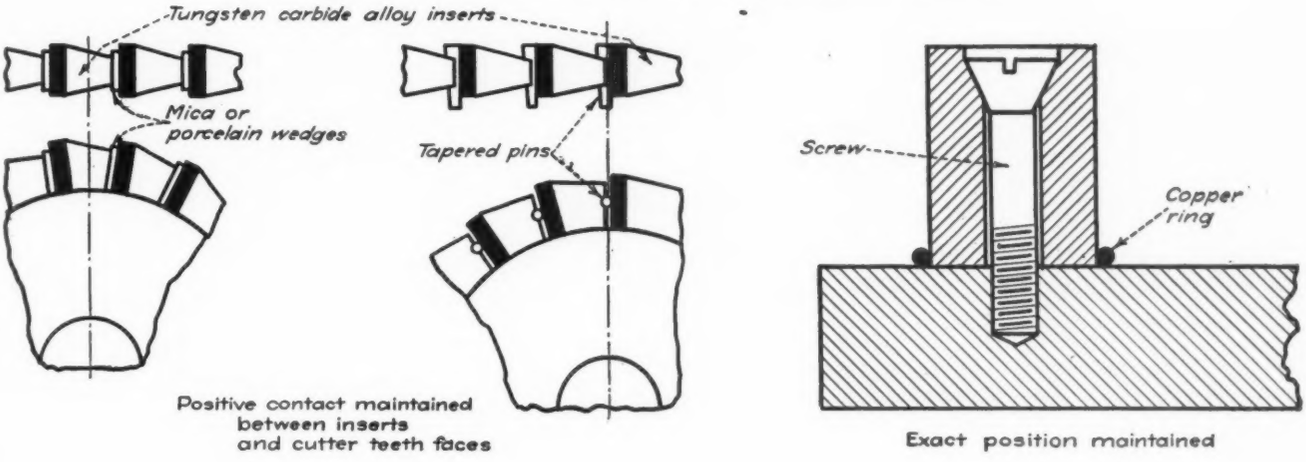
Straight seems in sheet metal can be interlocked. Wire or strip sometimes rolled into joint



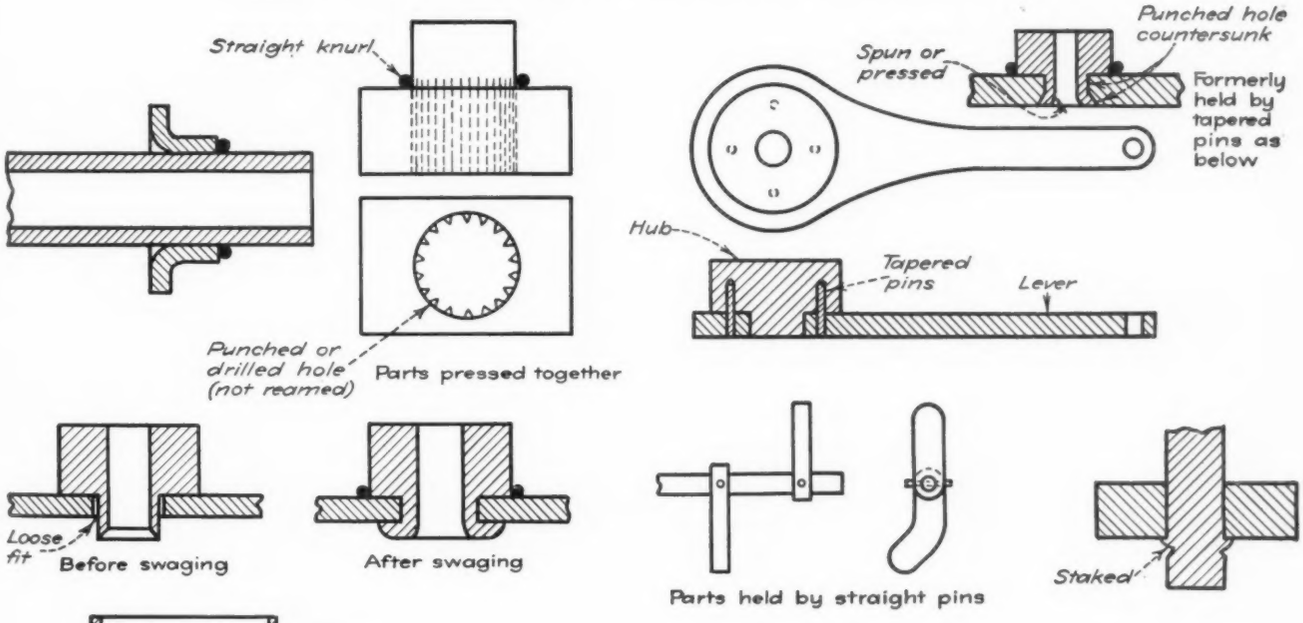
Rings will hold shape when interlocked, square better

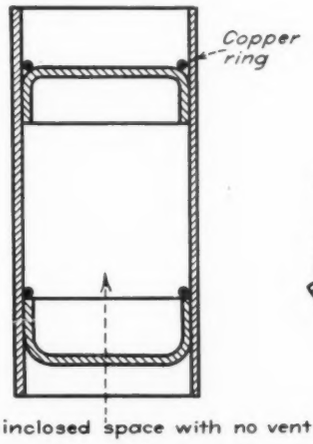
Dimensions of Parts During Brazing

POSITIONS HELD BY WEDGES, PINS, AND SCREWS

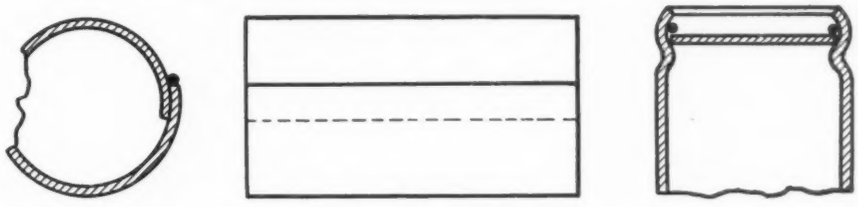


PERMANT AND TEMPORARY METHODS OF HOLDING PARTS





EXAMPLES OF FABRICATION METHODS THAT MAY NOT KEEP DIMENSIONS OR MAY NOT HOLD



Uses of Shot Peening Other Than for Fatigue Durability

L. J. WIESCHHAUS
American Wheelabrator and Equipment Corporation

New, strange and common applications of shot peening, excepting applications for fatigue durability. Resistance of materials to stress corrosion cracking along with tabular data from reports of the National Defense Research Committee (NA-115) are discussed. Suggestions to guide the shot peening of plain and thrust bearings are included.

WHILE most research on the subject of shot peening has been directed toward its effect on the fatigue of metals, other phases of the subject have not been completely neglected. Among the interesting and useful applications that have been developed are the use of shot peening to inhibit stress corrosion cracking, to reduce porosity in metal parts subjected to pneumatic and hydraulic pressures, to test the adherence of silver plate, to improve the lubricating properties of plain bearings and to replace polishing operations.

The effect of shot peening on the static and impact strengths of materials, on residual stress, corrosion, size and shape of parts, hardness, surface roughness and friction, microstructure, cavitation and on surface failures such as pitting, scoring, scuffing, fretting, corrosion and galling, however interesting as research, have not resulted in useful developments. This statement applies to the status today; it is not to be interpreted as a prediction about the developments of the future. In fact, further research will be required before a fair appraisal can be made of the effects of shot peening in many of these categories.

Stress Corrosion Cracking

Spontaneous cracking of metal resulting from the combined effect of high stress and corrosive attack can be inhibited by shot peening. Some laboratory tests made during the war at the Research Laboratories Division of the General Motors Corporation first revealed the possibility of protection by shot peening from stress corrosion cracking. Since some of the magnesium alloys had exhibited a tendency to crack under stress in a corrosive atmosphere, certain magnesium alloys were the first to be tested under laboratory or accelerated conditions. Later brass, mild steel, and stainless steel were tested.

Test specimens of magnesium alloy, AMC-57SH, 1/16 × 3/4 × 6 in. were stressed by bending as shown in Fig. 1. A part of the mounted specimens were peened to 0.003A intensity after which they were cleaned to remove traces of iron dust by immersion for 30 min. in 10 percent chromic acid followed by immersion for 20 min. in 25 percent hydrofluoric acid. Unpeened mounted specimens were cleaned in like manner. Then the specimens were immersed in the corrosive solution consisting of 20 g. of potassium chromate and 35 g. of sodium chloride per liter of water and having a pH value of 9.6. The unpeened specimens failed in a couple of minutes; the peened specimens exhibited no cracking or corrosion after 10 days.

In another test on specimens of AMC-52SH magnesium alloy, glass beads of 0.010 in. nominal diameter instead of iron shot were used in the peening operation. This made the acid wash after peening unnecessary. The peened specimens after immersion in the test brine for 12 days showed no stress corrosion cracking.

Drawn unannealed cups of cartridge brass (70 Cu 30 Zn) 0.040 in. thick were tested in a solution of one percent mercurous nitrate containing one percent of concentrated nitric acid. Four unpeened cups developed longitudinal cracks within from 3 min. to one hour. Three other cups were shot peened on both the inside and outside surfaces before immersion in the corrosive solution. Two of the cups were removed from the solution after 16 hours and the third after 24 hours. None had developed stress corrosion cracks.

Another interesting series of stress corrosion tests is reported by Northrop Aircraft, Inc. The test strips 0.080 × ½ × 11-½ in., were cut from J-1H rolled magnesium sheet. The strips were bent to an arc of 4 in. radius over a wooden block, clamped at both ends, immersed in the corroding solution and the time to failure recorded, Table I. This bend radius stressed the material beyond the yield point.

The corrosive solution consisted of

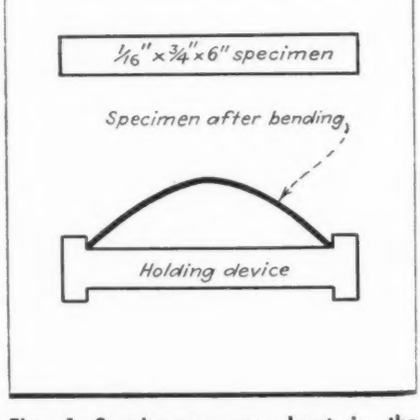


Fig. 1—Specimens were bent in the manner of a column in a vice and fitted to holding straps as shown wherein the bending stress was maintained.

20 g. of potassium chromate and 35 g. of sodium chloride per liter of tap water. Hydrochloric acid was added as necessary to maintain a pH value of 6.2. The tabulated data show that shot peening is much more beneficial when applied to mounted specimens under stress than to the unstressed specimens. They show also that failure takes place by general corrosion if the specimens are not chemically treated to remove iron particles after peening.

Not all attempts to inhibit stress corrosion cracking by shot peening have been successful. Neither have the reasons for the failures always been established. Table II contains data from a series of unfavorable tests. The specimens were round extrusions of J-1 magnesium alloy. The test section was ½-in. in diameter, both the peened and non-peened specimens being ground to size and shape of a standard tensile test specimen. Shot peening to 0.011A intensity on the neck of the specimen was used.

A constant tensile load was maintained on the test specimens, which were immersed in the corroding solution. Two solutions were used: One was a 3 percent solution of sodium chloride at 95 deg. F.; the other was a 3.5 percent sodium chloride plus a 2 percent potassium chromate. After shot peening some of the surfaces were degreased, followed by the No. 7 Dow chemical treatment, which includes dipping in hydrofluoric acid. These results parallel those for fatigue tests wherein shot peening offers little or no advantage where parts are sub-

Table I—Stress Corrosion Cracking of Peened and Nonpeened Specimens of J-1H Rolled Magnesium Sheet

Radius of block, in.	Condition of Specimen	Pressure of blast, lb. per sq. in.	Time to failure, hours	Remarks
7.5	Plain with sawed edges		1/4	Failed
4	Plain with sawed edges		11/60	Failed
4	Plain with sawed edges		1/30	Failed
4	Plain with smooth edges		3/20	Failed
4	Shot peened after stressing. Surfaces untreated	30	192	Failed by general corrosion
4	"	30	192	Failed by general corrosion
4	"	30	96	Failed by general corrosion
4	"	40	52	Failed by general corrosion
4	"	40	190	Failed by general corrosion
4	"	40	58	Failed by general corrosion
4	"	50	90	Failed by general corrosion
4	"	50	190	Failed by general corrosion
4	"	50	189	Failed by general corrosion
4	"	60	186	Failed by general corrosion
4	"	60	119	Failed by general corrosion
4	Shot peened after stressing. Plus surface treatment	30	264	Failed by general corrosion
4	"	30	81	Failed by general corrosion
4	"	40	624	Did not fail
4	"	40	624	Did not fail
4	"	50	624	Did not fail
4	"	50	624	Did not fail
4	"	60	141	Failed, stress corrosion
4	"	60	461	Failed, general corrosion
4	Shot peened before stressing. Plus surface treatment	30	1.75	Failed, stress corrosion
4	"	30	4.50	Failed, stress corrosion
4	"	30	1.60	Failed, stress corrosion
4	"	30	864	Failed, general corrosion
4	"	40	5.75	Failed, stress corrosion
4	"	40	768	Failed, general corrosion
4	"	40	740	Failed, general corrosion
4	"	40	528	Failed, general corrosion
4	"	50	384	Failed, stress corrosion
4	"	50	588	Failed, stress corrosion
4	"	50	0.25	Failed, stress corrosion
4	"	50	768	Failed, stress corrosion
4	"	60	415.5	Failed, stress corrosion
4	"	60	912	Failed, stress corrosion
4	"	60	0.50	Failed, stress corrosion
4	"	60	730	Failed, stress corrosion

Table II—Effect of Shot Peening on Resistance of Extruded J-1 Magnesium to Stress Corrosion Cracking (Tensile Load)

Alloy	Surface condition	3 percent Na Cl		3.5 percent Na Cl† 2 percent $K_2C_rO_4$	
		Stress, lb. per sq. in.	Time to failure, min.	Stress, lb. per sq. in.	Time to failure, min.
J-1 Extrusion	Blasted	38,000	180	38,000	1
"	"	36,000	180	36,000	1
"	"	34,000	180	34,000	1
"	"	32,000	280	32,000	3
"	Blasted plus DOW No. 7	38,000	90	38,000	1
"	" " " "	36,000	90	36,000	2
"	" " " "	32,000	14,500	34,000	1
"	" " " "			32,000	2
"	Machined	38,000	1,200		
"		36,000	9,000		
"		34,000	27,000		
"		32,000	36,000		

jected to direct tensile or compressive stresses but is effective for flexural stress.

Results of a series of tests on stainless steel specimens are given in Table III. The test specimens, bent to sustain a calculated fiber stress of 90 percent of the yield strength, were immersed in solutions of hydrated magnesium chloride of various pH values. The passivating treatment consisted of immersion in 20 percent acid solution for one-half hour before testing. Several of the peened specimens were immersed successively in the different solution.

Most of the foregoing data have been extracted from the NA-115 reports (Parts I, II and III) of the National Defense Research Committee of the Office of Scientific Research and Development. These reports present other data on stress corrosion cracking, as well as data on other phases of shot peening and many data on the effects of shot peening on fatigue. Except for the data on fatigue, Table III is an index of the case histories covered in the three parts of the report.

Porosity in Metals

About two years ago a manufacturer was confronted with leakage in some aluminum alloy die castings. The test procedure specifies the checking of each batch of castings. Several samples are immersed in water and subjected to an internal air pressure of 35 lb. per sq. in. Whenever leakage of the samples occur, every unit in the batch has to be tested.

On one type of casting, rejects because of leakage ran as high as 50 percent in the "as cast" condition. On a similar type of casting, which is made under more rigid foundry control, rejects because of leakage in the "as cast" condition were approximately 16 percent.

The manufacturer, almost in desperation, tried shot peening the specimens before testing. This proved so promising that shot peening equipment was installed in the production line. After almost a year of operation and observation, the process is regarded as successful. The leakage that was 50 percent dropped to 20 percent, and that which was 16 percent dropped to 4 percent.

This example is cited not as a recommended usage for shot peening but because it is an out-of-the-ordinary application to which shot peening has been put. Porosity of the casting, of course, except for the surface layer directly affected by the peening action, is not reduced by the shot peening. Additional successful applications will be required before the author, as well as others, will be convinced that shot peening is a satisfactory cure for porosity.

Silver Plate Adhesion

Frank D. Hallworth, Pratt and Whitney Aircraft Division, describes a method of determining the adhesion of silver plate by the use of shot peening. ("Bond testing of Silver Plated Engine Bearings", *Automotive and Aviation Industries,* July 15, 1946.) The test is based upon the principle that the hammering action of the shot produces deformation of the silver. If the bond is poor so that the silver is unrestrained by the steel backing, the silver will extend or flow and become blistered, Fig. 2. The intensity of peening must be adjusted for the thickness of the plating because a greater intensity is required to cause thick nonadherent silver to blister than thin nonadherent plating, Fig. 3. Mr. Hallworth points out that the test will not consistently detect faults in plated areas having slight adhesion but that nonadherent areas $\frac{1}{4}$ in. square and larger will be discovered without fail.

This test can be applied to any silver plated surface regardless of size or shape. If the finished surface must be smooth, then the plating must be thick enough to permit removal of the ridges and peaks caused by peening. Fig. 4 shows the minimum extra thickness of plating

Table III—Effect of Shot Peening on the Resistance of Stainless Steel Specimens to Stress Corrosion Cracking (Bending Load)

Test solution	Spec. No.	Treatment (see Notes)	Results
60 percent hydrated magnesium chloride pH of 5.4	1	A	Failed after approximately 650 hr.
	2	B	No failure at more than 2,000 hr.
	3	B	" " " " " " "
	4	B	" " " " " " "
	5	C	" " " " " " "
	6	C	" " " " " " "
	7	C	" " " " " " "
60 percent hydrated magnesium chloride pH of 3	8	A	Failed after approximately 120 hr.
	2	B	No failure after more than 450 hr.
	3	B	" " " " " " "
	4	B	" " " " " " "
	5	C	" " " " " " "
	6	C	" " " " " " "
	7	C	" " " " " " "
60 percent hydrated magnesium chloride pH of 2.2	9	A	Failed after approximately 40 hr.
	2	B	No failure after more than 400 hr.
	3	B	" " " " " " "
	4	B	" " " " " " "
	5	C	" " " " " " "
	6	C	" " " " " " "
	7	C	" " " " " " "
42 percent anhydrous magnesium chloride No acidification	10	A	Failed after only a few hours
	2	B	No failure after more than 300 hr.
	3	B	" " " " " " "
	5	C	Failed at approximately 210 hr.
	6	C	" " " " "
42 percent anhydrous magnesium chloride No acidification	11	A	Failed after approximately 75 hours
	12	B	Loading tie rod failed at approx. 75 hr.
	13	B	No failure after 1,150 hr.
	14	C	Loading tie rod failed at approx. 175 hr.
	15	C	Failed at 1,000 hr.

Notes: A — Pickled, polished then passivated
B — Pickled, polished, stressed after peening and then passivated
C — Pickled, polished, peened after stressing and then passivated

Pratt & Whitney Aircraft Div., United Aircraft Corp.

Fig. 2—Articulated rod-pins with defectively-bonded silver plate after shot peening under test.

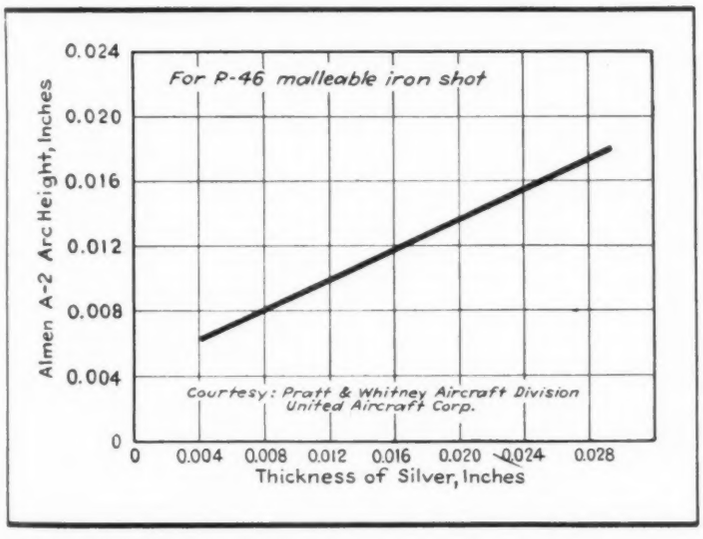


Fig. 3—Minimum shot peening intensity required to cause various thicknesses of badly bonded silver to blister.

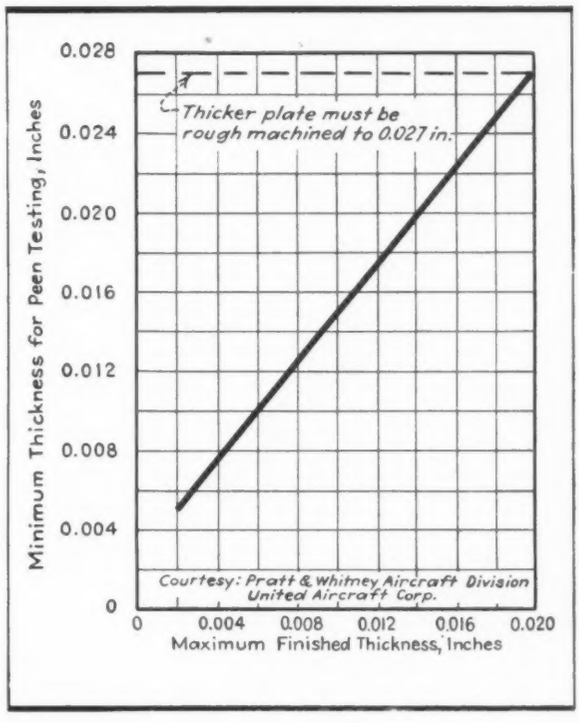


Fig. 4—Minimum thickness of silver to allow peen testing before finishing to any maximum finished thickness.

required when the surface roughness and work hardening of shot peening are to be removed by a finish machining operation after shot peening.

Improved Lubrication Properties

Another application of shot peening that has been receiving increasing attention is its use as a means of improving the oil retention properties of plain and thrust bearings. The peening action of the shot results in small dents on the bearing surface. These dents serve as small oil reservoirs and insure a constant, adequate supply of lubricant to the areas which need it most. When heavy loads are applied to bearings with highly polished surfaces, there is a tendency for the oil to be squeezed out at those spots where the two surfaces are pressed closest together. By insuring a constant oil supply in these critical regions, the small peening dents aid materially in increasing bearing life.

Special technique is required for this application and work is still underway to determine the optimum conditions for maxamum bearing life and maximum peening economy. Indications are that the most desirable conditions include a relatively high intensity, to provide sizeable dents for oil reservoirs, and "sparse" cover-

Table IV—Matter Available in NA-115 Reports Exclusive of Case Histories on Fatigue Durability

Property	Case No.	Page No.	Plain carbon steel	Alloy steel SAE, others	NE alloy steel	Aluminum	Magnesium	Others
Static strength	1	85†						cast iron
	2	87†		4130		Alclad 24S-T		stainless steel
	3	88†					J-1H	
	4	180						aluminum bronze
	5	182			9420, 9450, 9420 carb.			
	6	184					JS-1H, FS-1H	
Impact	1	65*						Y-1315 emergency
	2	67*		4115				
	3	69*		WD-4615				
	4	90†		4640, 8617, 8630, 3312				
	5	92†						GM Y-1315A
	6	94†	1015					
	7	187		GM 4220				
	8	188		8615, GM-Y-1315-A				
Size change	1	72*						
	2	72*						
	3	96†				13X, 195T6		
	5	191		4820, 4640				
	6	192		steel				
Hardness	1	98†	1020					
	2	100†		X 4340				
	3	101†		4130		Alclad 24S-T		stainless steel
	4	195						forging
Friction	1	103†	1020					
	2	104†		4140				
Stress corrosion	1	81*					AMC-57SH	
	2	85*					DOW J-1M	
	3	88*					DOW J-1 ext.	
	4	90*					DOW J-1H	
	5	92*					DOW J-1H	
	6	94*					J-1H	
	7	106†						brass
	8	108†					J-1H	
	9	110†					AMC-57SH	
							AMC-52SH	
	10	112†					AMC-57SH	
	11	199						brass 70/30
	12	201						brass 70/30
	13	203						brass 70/30
	14	205						brass 68.6/31.3
	15	207					J1-H welded	
	16	209					JS-1H, FS-1H	
	17	211						stainless steel
	18	213	low carbon bessemer					
Corrosion	1	114†				Alclad 24S-T		stainless steel
	2	216						cast iron
	3	217						zinc plated
	4	217	mild steel				Mg alloy	
Surface roughness	1	116†	1020					
Surface failure	1	119†		4615				
	2	121†	steel					
	3	122†	steel					
	4	123†						stainless steel
	5	219			8749			
	6	220						aircraft engine cylinder barrel bares
	7	221		4140				
	8	222		AMS-6294				
	9	223		AMS-6240				
	10	224				alloy		
	11	225						cast valve tappets
	12	226						spiral bevel gear sets

* Page No. in Part I of NA-115 Report;
† Part II of Report; others to Part III

age, to leave a maximum of bearing surface. High intensities are obtained by increasing the wheel speed (which increases shot velocity) and/or using larger shot. The degree of coverage is controlled by the rate of travel of the work through the blast—sparse coverage is obtained by increasing the conveyor speed which in turn decreases the length of time the work will be exposed to the abrasive blast and thereby reduces the number of shot that strike the work.

Not enough data are available at the present time to permit the selection of any one combination of intensity and coverage as being best suited for this application. The practice has been to decide each new problem on its merits. A series of specimens are run at various intensities and conveyor speeds and then the parts are tested in actual operation to determine which set of conditions give the best results.

Almen test equipment has not proved satisfactory for measuring the effective intensity, the reason being that the "arc height" measured on an Almen gauge is proportional to the intensity only when complete coverage is obtained. For the degree of coverage used in this application the arc height produced is extremely small and practically valueless as a means of control.

Peening for Surface Finish

Shot peening provides a good exterior surface on parts where the roughness resulting from the peening is not objectionable or where roughness is desirable as on quality silver and plate ware. On the latter a dull pebble finish effect is obtained. Sometimes such surfaces are electropolished after peening to obtain a brilliant, sparkle finish. Under such circumstances the preparatory process is frequently referred to as shot blasting, although the author prefers to restrict the term shot blasting strictly to processes of cleaning surfaces.

Since a stream of shot can be directed into corners, depressions and recesses, shot peening is sometimes a more effective method of finishing rough, uneven surfaces than mechanical methods of polishing. Toolmarks, burrs, and surface defects are peened down so as to be less noticeable on the rough surface left by peening.

Peened finish instead of polishing saves time and labor. The peening of Allison engine connecting rods saved 36 man hours per engine, plus floor space, abrasive and overhead when shot peening replaced polishing as the finishing process. This is really the by-product of peening to effect an increase of from 4 to 10 times the fatigue life. (See "New Trails in Surface Finishing Aircraft Engine Parts" in *Steel*, July 5, 1943.) Another example, which is discussed in the same article, is that of the Packard Motor Car Company where 42 man hours per marine engine were saved by shot peening.

Case Histories In Patent Law

H. A. TOULMIN, JR.

[EDITOR'S NOTE: These explanations of the law in specific patent cases are not intended to supplant the services of a patent attorney, whose accurate advice is necessary to handle individual patent problems. The purpose of these explanations is to give a better general understanding of patent law.]

NO. 11

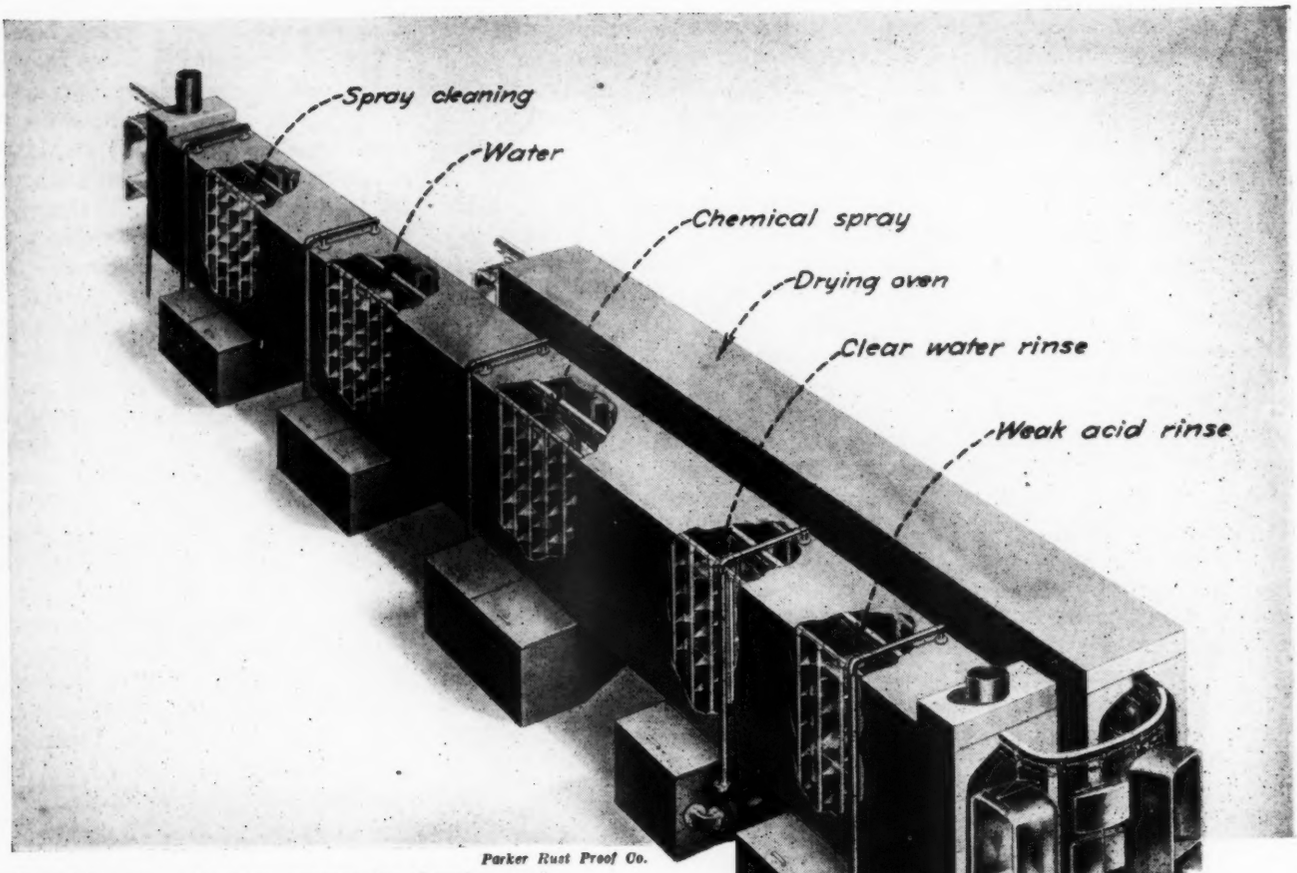
QUESTION: Can a patent be held invalid on the basis of a public use more than one year (or two years under the old law) according to the statute, prior to the invention when this prior use does not take place until after the patent is filed or at the time of its filing?

ANSWER: A curious case arose which has had a great effect upon the patent law of the United States in a recent decision of the Supreme Court of the United States. It was the case of Muncie Gear Co. v. Outboard Co., 315 U. S. 759, in which the claims were added into the patent in suit for overcoming cavitation in the operation of outboard motors that included a new feature that was not disclosed as the invention in the original application.

The Supreme Court established the rule that an invention presented in claims, whether at the time of filing the application or presented in claims at a later date, must be presented at a time within the statutory period of a prior public use. At the time of deciding this case the statutory time was two years but now it is one year. Whether it is two or one years, it is necessary for a patentee to have presented his claims to a particular invention in his application within the statutory period of one or two years or his patent will be held invalid.

It has long been the practice of patent attorneys in amending patent applications to amend them on the theory that if they were supported by the original application that anything that occurred not more than two years (or one year under the new law) prior to the filing of the new claims was not important so long as the original filing date of the patent came within the two year or one year period. This the Supreme Court now holds is untrue.

It is necessary to file your claims to an invention either strictly based upon the original claims and the original application as disclosed by it and the drawings or to be sure that any new claims on new subject matter or a new angle of the invention be submitted within the statutory period so as not to be anticipated by any prior public use. As the court said, "The claims in question are invalid if there was a public use, or sale, of the device which they are claimed to cover, more than two years before the first disclosure thereof to the Patent Office." Thus in this case where competitors had put out the subject matter of the claims in suit more than two years before the claims were filed in the Patent Office, although later than the date of filing the patent application, this brought about a prior use of the claims and they were invalidated.



Parker Rust Proof Co.

Complete spray chamber process for cleaning and chemically treating either steel, aluminum or zinc.

Treatments for Metal Surfaces Prior to Painting

E. F. HICKSON and W. C. PORTER

Paint, Varnish and Lacquer Section, National Bureau of Standards

SINCE metal products are painted either for protective or decorative purposes, the paint coating must remain as a continuous film over the metal. Much research has been done to determine the best way to keep the coating as a continuous film. Current practice indicates that thorough cleaning and the use of a chemical wash solution, or an electro-chemical treatment, are prerequisites to obtaining and maintaining a continuous paint film. Used in the manufacture of painted metal consumer products, cold or hot chemical solutions convert the metallic surface to a non-metallic, water insoluble, tightly adherent coat.

Cold-wash solutions are usually made of phosphoric acid or a chromate-phosphoric acid mixture with grease solvents. These washes are used for preparing a large surface away from the factory, or where the hot application method is not available. The U. S. Army Engineers specify the use of cold-wash treatments in the maintenance of steel structures near dams.

Hot solutions, applied under controlled conditions, produce a more uniform coating and are more effective than the cold-wash treatment. Such solutions are usually made of a metallic acid phosphate and oxidizing and wetting agents. Hot washes may be applied by dipping or spraying. A conveyor passing through five separate spray booths gives a continuous hot-wash. The parts are degreased, water rinsed, chemically treated, water rinsed and finally rinsed in a weak solution of chromic or phosphoric-chromic acid. The articles then enter a drying oven after which they are ready for painting.

It must be emphasized that these pretreatments do not take the place of a priming paint and provide little corrosion resistance. However, these chemical treatments improve the adhesion properties and resultant durability of applied paints, enamels and lacquers.

Metals are protected by the paint in contact with them. Since it is difficult to be sure that every part of the unit is covered by the priming coat, it is essential that the second coat be of the same composition as the priming coat. A slight difference in color will aid in applying the second coat evenly. The succeeding coats protect the underlying paint and furnish the desired color. White and tinted paints are less durable, though more expensive, than dark-colored paints. However, white and tinted finish coats are used where appearance and visibility or heat reflection make a light color imperative.

Steel

A chemical treatment is used on steel to provide an intermediary bond between the metal and the initial coat of paint. This bond is in the form of a film with good properties of adhesion and acts as a rust inhibitive surface.

Before anything can be done to the surface of the metal to protect it, it must be clean. Oil and grease, rust, dirt, scale, old paint and moisture must be removed. Any of these foreign materials under a coating of paint will cause a weakness in the film and an eventual cracking of the paint. The oil and grease should be removed first. This is done by wiping the surface with clean cloths and mineral spirits or carbon tetrachloride. The liquid and cloths should be changed frequently to avoid leaving a thin, greasy film on the surface.

The problem of scale removal is an old one. If the scale is continuous it provides considerable protection to the steel. However, partial removal of scale can be more injurious than no removal at all. It is agreed that the best practice on structural steel is to remove all the scale and rust. In a mill, scale can be removed by sandblasting or pickling. After erection, scale can best be removed from a steel structure by controlled sand or steel grit blasting. The more common practice is to use wire brushes, manually or mechanically operated, and scrapers.

If chemical treating solutions are to be used, they should be applied to the steel as soon after cleaning as possible. There are many proprietary brands of pre-treating solutions available. An inhibitive wash specified in U. S. Army Specification No. 3-205 has the following composition:

Orthophosphoric acid (75 per cent H_3PO_4)	12 gal. (1 carboy)
Chromium sulphate (water soluble)	25 lb.
Monobutyl phenyl phenol sodium sulfonate (detergent)	1½ gal.
Ethylene glycol monoethyl ether (cellosolve)	6 gal.
Water to make	160 gal.

When used cold this inhibitor can be applied by dipping or brushing. Within not less than 1 hr. after application the residue should be removed by wiping with damp cloths or by flushing with hot water. The surface should be dried and the priming paint should be applied before corrosion occurs.

Hot phosphate solutions may be applied by immersion or mechanical spraying methods. In the immersion method it is important to replenish the solution at intervals as the chemical strength of the bath is reduced. The temperature and time of immersion should be controlled to produce a uniform and tightly attached phosphate coating to the steel. The part being processed is immersed for a period from 30 sec. to 5 min. at a temperature from 170 to 185 deg. F. In the spraying method the temperature of the solution should be in the range between 140 and 155 deg. F. Spraying time will be from 10 sec. to 2 min., depending on the size and shape of the part.

Galvanized Metal and Sheet Zinc

Many explanations have been advanced for the lack of good adhesive qualities of paint on galvanized metal. Zinc salts may be left on the surface during the galvanizing process; certain chemical reactions may take place in the paint film itself, or reactive decomposition products in the presence of moisture may react with the metal at the interface. Zinc formate, which forms at the interface between the paint and the metal zinc surface, has also been suggested as one of the causes for the poor adhesion.

Before pretreating galvanized metal all dirt and grease must be removed. Turpentine, mineral spirits or other cleaning solvents can be used to do this. After cleaning, the galvanized metal should be chemically treated. Some solutions have a surface roughening, etching action, while the better treatments change the surface chemically. The best solutions, such as the zinc phosphate and phosphate-chromate types, deposit a non-metallic, water-insoluble, phosphate coating that has good adhesive qualities and retards corrosion under the paint film.

Since the zinc on galvanized metal offers a better protection from rusting than any paint coating, it is not necessary or advisable to apply thick or as many coats of paint to galvanized metal as to ordinary iron and steel. Zinc dust-zinc oxide paint can be used for both new and old galvanized parts. Three types of vehicles are used with this pigment to protect against various atmospheres. Linseed oil and glyceral phthalate are vehicles used where the final product will be exposed to general weathering. A phenolic resin vehicle is used where severe moisture conditions prevail. The paints containing glyceryl phthalate or phenolic resin vehicles may be air-dried or baked at temperatures up to 380 deg. Fahrenheit.

Aluminum and Aluminum Alloys

With the upward trend in the use of aluminum products some attention must be given to the preparation of it and its alloys prior to painting. With a clean grease-free surface there are no particular problems in painting aluminum, but when the final products are to be exposed to severe corrosive conditions the surfaces should be chemically treated to form a non-reactive coating on the base metal. This coating inhibits corrosion and present a good bonding surface to the paint.

Before any painting or treating can be done, the aluminum should be cleaned with an inhibited alkali cleaner. This is followed by one of the treatments listed; depending on the type of conditions to be met in service. The parts can be immersed in phosphoric or chromic acid solutions. They can be treated in an aqueous solution of phosphoric acid with organic grease solvents and emulsifiers, see formula used with steel treatment. A solution to be

brushed on the surface of aluminum parts is composed of 20 percent, by volume of 85 percent phosphoric acid and 80 percent denatured alcohol. Another method forms an electrochemical oxide coating by use of an anodic treatment with an electrolyte.

Where severe exposure conditions are to be met the aluminum surface is treated with a hot, metal acid phosphate solution followed by a chromic or phosphoric-chromic acid rinse. A zinc chromate primer in a relatively non-permeable vehicle should then be applied. Primer pigment meeting Army-Navy Specification AN-TT-P-656b is composed of 85 percent zinc chromate yellow and 15 percent magnesium silicate. If such a primer is not available, an iron oxide primer can be used.

Good practice for pretreating aluminum in very corrosive atmospheres can be found in the methods used by the Navy on aluminum aircraft parts. All aluminum surfaces to be painted are first given an anodic, electrochemical treatment. Aluminum alloy castings with integrally cast non-aluminum inserts are treated with an approved alkaline chromate solution. Certain land plane parts are immersed for from 2 to 5 min. in a chromic acid surface bath of 5 percent chromic anhydride and 95 percent water, at a temperature of 120 to 140 deg. F. This treatment is used only when the other two are not available.

Lead, Copper and Brass

When these three metals are to be painted, a chemical solution can be used to prepare the surface. This treatment converts the metal surface to an oxalate coating.

Magnesium Alloys

Magnesium metal readily acquires a thin coating of magnesium hydroxide when exposed to moist air or when immersed in water. The resulting alkalinity has been suggested as one of the causes for poor paint adherence to untreated magnesium alloys. Good paint adherence can be obtained on a clean surface by using a chemical or anodic pretreatment.

The surfaces of magnesium alloy parts can be cleaned by organic solvents or by immersion in boiling alkaline cleaners used for aluminum and steel. A solution of the following composition is satisfactory:

Sodium carbonate (soda ash)	4 oz.
Trisodium phosphate	4 oz.
Easily soluble soaps or wetting agents	0.1 oz.
Water to make	1 gal.

Sand castings, blasted parts and parts that contain dirt not removable by organic solvents or alkaline cleaners, or which show visible surface oxidation, should be cleaned in an acid pickling solution. A nitric-sulphuric acid pickle removes surface oxidation, corrosion products and sand from rough, unmachined parts or castings. The part is dipped for 10 sec. at room temperature in the solution:

Water	90 parts by volume
Con. nitric acid	8 parts by volume
Con. sulphuric acid	2 parts by volume

A dip for 5 min. in a hydrofluoric acid pickle at room temperature can be used for removing sand or the effect of blasting on all parts requiring close tolerances but it is not satisfactory for removing surface oxidation and corrosion products. This solution contains:

Water	2 parts by volume
Hydrofluoric acid (50 percent)	1 part by volume

Operated at room temperature or at 90 to 100 deg. C., a chromic acid pickle is used for periods of 1 to 15 min., depending on the temperature. It can be used for removing surface oxidation and corrosion products, and is particularly suitable for close tolerance parts. It will not remove sand or the effects of blasting and should not be used for parts containing copper base inserts unless they are masked off. This bath is made up of:

Chromium trioxide (CrO_3)	1.5 lb.
Water to make	1 gal.

After the parts have been completely cleaned a chemical or anodic treatment is used before painting. Chemical treatments of the chrome type are good but cannot be used where close dimensional tolerances are required. The parts are dipped for ½ to 2 min. at room temperature in an aqueous solution of:

Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	1.5 lb.
Nitric acid (sp. gr. 1.42)	1.5 pints
Water to make	1 gal.

or

Chromium trioxide (CrO_3)	1 lb.
Nitric acid (sp. gr. 1.42)	0.9 pints
Water to make	1 gal.

To improve the color and quality of the coating, the parts are exposed to the air for at least 5 sec. after dipping. They are then washed in cold running water and rinsed in hot water.

To thoroughly protect magnesium alloy parts and yet maintain their exact dimensions a galvanic anodizing treatment, such as developed for use on Army and Navy aircraft parts, should be used. The parts are immersed for 5 min., at room temperature, in a water solution containing 15 to 20 percent by weight of hydrofluoric acid. They are rinsed in cold running water and then immersed and galvanically anodized in a bath at room temperature having the following composition:

Ammonium sulphate ($(NH_4)_2SO_4$)	4 oz.
Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	4 oz.
Ammonia (sp, gr. 0.880)	¼ fluid oz.
Water to make	1 gal.

The electrical circuit is regulated to maintain a current density between 2 and 10 amp. per sq. ft. The time of treatment should be long enough to produce a uniform black coating; never be less than 70 amp-min. per sq. ft. The proper acidity of the bath can be controlled by maintaining the pH between 5.6 and 6.2 with additions of a solution containing 5 percent of chromium trioxide and 5 percent of concentrated sulphuric acid by weight. The parts are washed in cold running water and rinsed in hot water.

After the surface has been treated and thoroughly dried it should be coated with a priming paint as soon as practicable. The priming paints are of the zinc chromate yellow type in a synthetic resin vehicle.

Conclusion

The application of a chemical treatment that deposits a uniform, finely crystalline, insoluble, non-metallic coating of the proper texture, is recognized as a distinct step in the progress of protecting surfaces against corrosion with organic materials. Many utility items for the household and the industrial field are being treated this way to insure their long life and pleasing appearance. It must be remembered, however, that chemical pretreatments do not in themselves retard corrosion. The chemically created coatings give the adhesive base needed by the anti-corrosive paints.

ENGINEERING ABSTRACTS

FOREIGN AND DOMESTIC ARTICLES

Industrial Research

From a paper, "Research in the Mechanical Industries" by J. F. Wilkes, Technical Director, Dearborn Chemical Company, presented before the Chicago Production Conference, Chicago, Ill.

RAILROADS. The trend of present railroad research is directed toward improvements that will increase efficiency of service, raise train operating speeds, reduce operating costs, modernize passenger equipment and increase the safety of operation. In the railroad industry, such research is not limited to the technical field, nor does it deal only with engineering problems and their solution. Active work also is in progress on economic, traffic, personnel and many other types of research.

In 1944, the Association of American Railroads estimated that the annual research expenditures of Class I railroads, which are directly contributing to the improvement of railroad transportation by either theoretical or applied research and including practical investigation in the shop and on the line, were approximately 7 million dollars. Direct expenditures for research by AAR have averaged over ½ million dollars a year and now are double that amount. The railroad supply industry is so closely allied with railroad research that their activities are largely cooperative. The most of the work done by railway supply companies to some extent is paid for by the railroad —partly in direct payroll and other costs, and partly in the price the railroads pay for equipment and supplies. It has been estimated that the railroad supply industries expend for research, a total of 8 million dollars annually—the total investment for laboratories and equipment exceeding 20 million dollars. We should not assume that all research facilities of the supply industry are directly aimed at railway improvements. On the contrary, the supply industries are becoming increasingly diversified, so that the percentage of their effort benefiting the railroads is decreasing.

On the percentage basis, using the 1944 railway gross earnings of 9 1/3 billions, the total expended for research by the railroads, AAR and the supply industry in that year represents only 1/6 of 1 percent of the gross railway revenue.

In general it is felt that these expenditures are not sufficient, and that railroads themselves must increase their emphasis on application of modern scientific developments in business.

However, much valuable research work has been completed, and the results obtained therefrom have been outstanding. With the railroad industry, and between the various technical groups performing research for the railroads, there exists very close cooperation and a free interchange of information; all work accomplished is largely available to all railroads. Consequently, a general benefit is derived from a relatively small expenditure for research.

Railroad research projects now under way, or which have already resulted in improvements, include: (1) Trend toward dieselization; (2) steam turbine locomotive, and steam turbo-electric locomotive; (3) coal burning gas turbine locomotive, ATASF and Bituminous Coal Research, Inc.; (4) thermic syphons, foam collapsing system, welded boilers, antifoam improvements; (5) radio control of switching, CTC, facsimile, train control, teletype billing; and (6) welded rail, mechanized maintenance of way equipment, and counter-balance studies.

AUTOMOTIVE. The automotive industry has made possible experimental and practical research on a broad scale. This work is not confined to the laboratories of the producers of automotive equipment; it has been extended to those of the suppliers of parts, materials and tools and has provided an impetus for research by colleges, by the Government, and by a number of private organizations.

This research has provided new materials, new uses for old materials, new manufacturing processes, new types of production equipment, new forms of tools, and new methods and standards of highway construction. To the extent permissible under competitive conditions, there has also been the free interchange of the information developed among manufacturers. This is an economy, for otherwise each company's own consumption would have to bear the cost of all the necessary research involved.

Many of the new developments that have resulted from research in the interest of the automotive industry have had a vital effect not only on the design, operation and production of motor vehicles, but also on other manufactured goods—radio, refrigerators, airplanes, stoves, washing machines, railroads, and even houses. Not only do manufacturers of such goods use the automotive industry's techniques of production but also the materials and applications it developed or caused to be developed.

Automotive research and related engineering activities might be grouped as: (1) Product engineering, or efforts, concerned with current models and those for immediate future, (2) development engineering for advanced design and experimentation in connection with future models, and (3) applied research or new application of known scientific laws and materials.

Throughout the past three decades, technological development of automotive equipment has progressed rapidly. From an engineering standpoint during the past three decades, developments have been designed to: (1) Reduce original cost, operating cost and cost of servicing and weight per hp; (2) improve durability, performance, ease of handling; and (3) increase safety, comfort, and appearance.

The modern automobile engine develops four times the hp. of that in the 1918 car, but is only 22 percent larger. Annual gasoline consumption per car rose 150 percent from 1919 to 1941, but the average annual mileage

per car tripled. Average car weight increased about 20 percent during this period. If the 1942 car had been built with the same materials used in 1918, it would have weighed twice as much and cost much more to operate. By utilization of mass-production methods, and improvement in raw materials, average factory price of automobiles dropped from $1,750 in 1919 to $778 in 1940. One such improvement was pre-graded steel, delivered "ready for use," eliminating faulty sheets and necessity for careful inspection during manufacture.

AVIATION. In the aviation industry, research is carried on by the larger manufacturers and airline companies, in their own laboratories and in private institutions. This work is financed by government grants, by Armed Forces, and by the aviation industry. Extensive research is being performed on development of power plants of radical new designs, including jet engines and gas turbines. It is predicted that large transport planes in the future, all would be powered with turbine-type engines rather than with present reciprocating type engines. The Lockheed "Constitution," now being tested, is designed to allow substitution of turbine engines for the piston type engines now installed. Jet propelled planes already have been proven practicable, although their rates of fuel consumption are still relatively high. Radical changes in wing and body design, such as Northrup "flying wing", now are under study. Counter-rotating propellors on a concentric shaft have been tested. The helicopter may be increasingly improved in the future. The general trend in aircraft research is to provide maximum safety, added comfort and speed, together with very economical operation and more intensive utilization. Blind landing equipment, improved navigation aids, and other wartime radar developments are being adapted to increase flight safety.

Cathode-Ray Compass

From "A Magnetic Compass With a Cathode-Ray Sensing Element" by Waldo H. Kliever and Richard R. Syrdal, Minneapolis-Honeywell Regulator Co. presented at A.I.E.E., Jan. 1947, New York, N. Y.

WHEN a cathode-ray oscilloscope is moved to different positions in the laboratory, the action of the earth's magnetic field deflects the rays and shifts the image on the screen. This principle is used to operate a newly developed cathode-ray compass.

As an aeronautical compass the cathode-ray system has a sensitivity of better than ¼ deg. and better than a ±1 deg. accuracy. Advantages include: (1) System has no iron to distort earth's field, (2) free from northerly turning error found in needle compasses, (3) electron beam has negligible time lag, (4) output in each axis is linear with magnetic field to values beyond the maximum horizontal field of the earth, and (5) changes in field intensity or voltage have little affect, for example a 25 percent change in voltage changes the reading less than ½ degree.

Instead of a screen, the compass tube has four target plates, as shown in Fig. 1, that collect the beam current. The tube is mounted vertically so that only the horizontal component of the earth's magnetic field deflects the beam. The deflection is always at right angles to the field, that is, toward the west, if the beam is directed downward. This deflection causes the current to vary in the respective target plates.

To facilitate measurement and amplification the cathode-ray beam is modulated in intensity with 400 cycles a.c. Each opposite pair of plates is connected in a push-pull circuit and the output, representing the difference in current between the plates, is proportional to the component of the magnetic field at right angles to the line through the centers of those plates.

Thus, the two outputs are proportional to two components H_x and H_y of the earth's horizontal magnetic field. If the tube is, for example, so aligned that H_x is parallel with the longitudinal axis of the plane, and H_y with the lateral, there is sufficient information to determine the plane's magnetic heading. The overall system consists of the special cathode-ray tube and a resolving mechanism.

The cathode-ray tube is 1 in. in diameter and 7 in. long overall including sockets. The target current is more than 1.5 milliamperes at 300 volts, with 95 percent of the cathode current reaching the targets as compared to 20 percent for ordinary cathode-ray tubes. The target plates are bevelled so that they overlap to prevent the loss of any electrons between the plates. This was found desirable not only because of the loss of current but because the stray electrons produced undesirable charges at other points of the tube. The inside of the glass is coated with conducting coating to prevent charging of the glass and resultant shift in the balance point. This coating is connected to the last anode. The tube has a focal spot about 10 mm. in diameter and deflects about 1.6 mm. with earth's horizontal field of 0.16 gauss, when operating at 300 volts. It operates in the model with 50 percent modulation with 400 cycle a.c. on the grid and a total average of 0.5 milliampere. Under these conditions the difference of a.c. amperes between target plates at right angles to 0.16 gauss is about 60 microamperes through an effective impedance of 160,000 ohms, or after the transformers, 0.25 volts across 10,000 ohms.

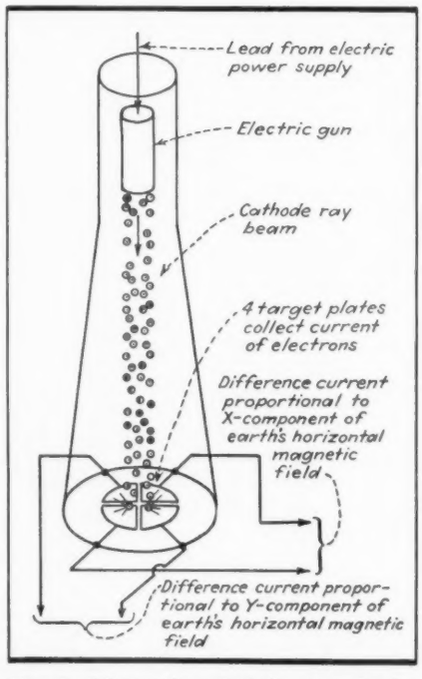

Lead from electric power supply
Electric gun
Cathode ray beam
4 target plates collect current of electrons
Difference current proportional to X-component of earth's horizontal magnetic field
Difference current proportional to Y-component of earth's horizontal magnetic field

Fig. 1—Schematic principle of cathode-ray compass using four target plates.

The tube is mounted in a non-ferrous metal housing on gimbals to maintain its vertical position. Connections are made through flexible leads. The tube is supported by rubber clamps against the glass; and the sockets, instead of being supports as in normal tube practice, are floating on the tube. To reduce the number of flex leads a voltage divider is made part of the tube mounting.

The tube gives two components of the earth's magnetic field that are then converted into the angle of the principal magnetic vector. The square potentio-

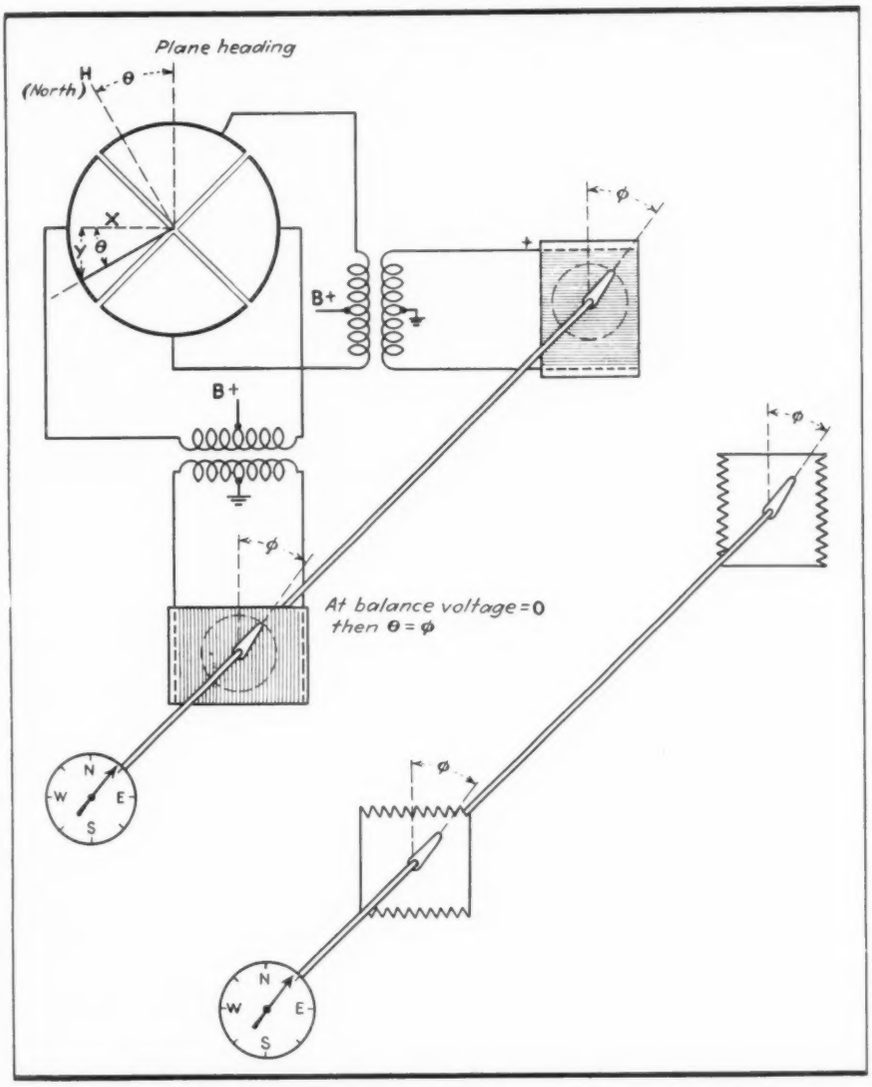


Fig. 2—Schematic showing operation of square potentiometer resolvers.

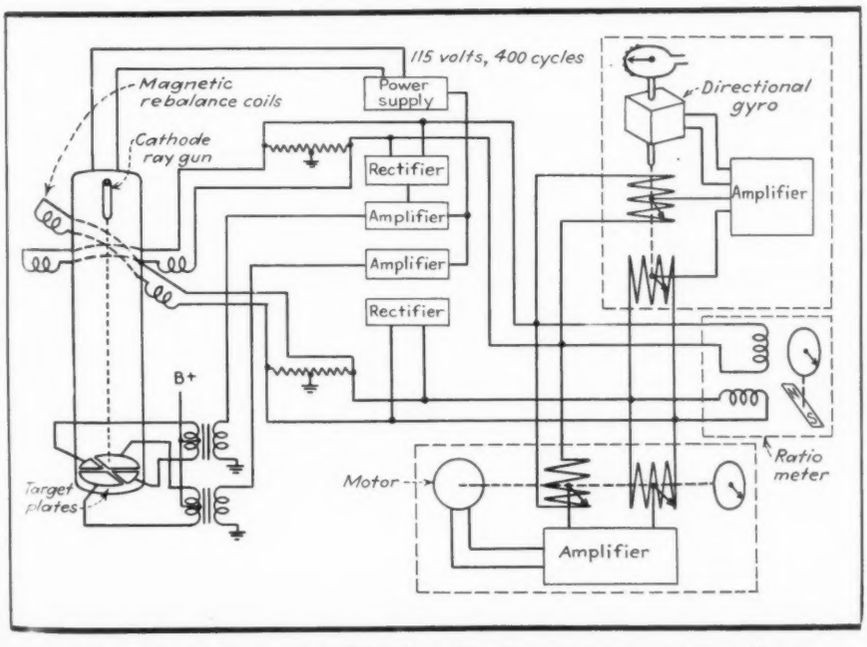


Fig. 3—Null rebalance with slave directional gyro, ratio meter, and servo.

meter resolver is composed of two wire wound cards of approximately square dimensions with a wiper that rotates in a circle as shown in the upper part of Fig. 2. When a voltage is applied across one of these potentiometers, which is grounded at the center of the circle, then the voltage between the wiper and ground will vary as the sine or cosine of the angle of the wiper, depending upon the position from which the angle is measured. As used with a compass, the two potentiometers are connected to the tube through transformers as shown in Fig. 2. An interesting variation of the square potentiometer, shown in lower part of Fig. 2, uses two straight line potentiometers comprising opposite sides of a square that is completed by solid conductors across the other two sides.

A magnetic compass gives a correct reading of the direction of the earth's horizontal field only if it is level. One solution is to hold the compass vertical with a vertical gyro but it is best to keep all iron away from the tube. Since the compass was designed for use with an autopilot, which already has a directional gyro, the compass was mounted pendulously in gimbals and the gyro slaved to it by a precession motor in the gyro operated by the compass signals. The operation of this system is similar to that of a gravity erection system on a vertical gyro. The signals to the gyro are not instantaneously correct because of accelerations of the airplane, but they generally have an accurate average, and the gyro has the ability to integrate them to obtain the average. During periods of known long-time accelerations, such as in turns, the precession is switched off.

As in the vertical gyro analogy, there are possible conditions of feedback between the gyro precession system and the airplane controlled by the gyro. To explain this condition briefly for the compass, when flying north, consider a slight bank introduced by, say, rough air. The plane starts to turn in the bank, which tilts the compass. The latter, because of the resulting azimuth error, calls for precession of the directional gyro that calls for more turning of the plane through the autopilot. After reaching the angle off course corresponding to the bank called for by the rate of precession, the process reverses and a continuous hunt follows. In flying south the feedback is negative, and there is stability. In flying east or west this azimuth hunt is not a problem, but some temporary changes in heading can result from longitudinal accelerations caused by changes in power or altitude. These effects have been studied both

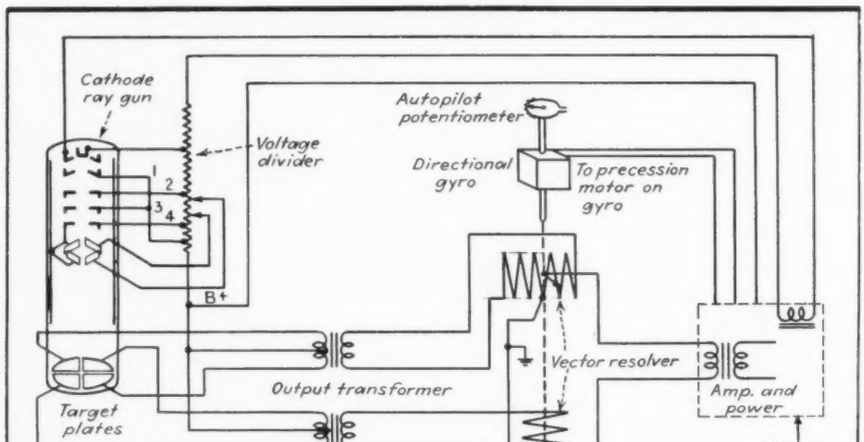


Fig. 4—Schematic of circuit of cathode ray compass showing connections to tube and how output operates a slave gyro to hold balanced condition.

theoretically and experimentally with good agreement and are not peculiar to this or any special compass design. The answer is a good gyro which can be operated with a low precession rate. Without going into too much quantitative detail, it can be said here that an unmodulated rate of about 4 deg. per min. has been found satisfactory.

Other possible applications of the cathode-ray compass include motorizing the tube in both axes for aligning itself with the earth's field and thus determine dip and latitude. With controlled voltage or rebalance coils it can measure intensity, as well as direction, of magnetic fields. Field changes as small as one-half milligauss are easily detectable. The tube could be used to control large coils to produce a field-free space.

Airborne Magnetic Detector

From a paper "Continuous Recording Sensitive Magnetometer" by Rodney F. Simons, Airborne Instruments Laboratory, Inc., presented at the annual meeting of Institute of Radio Engineers, New York, N. Y.

The techniques of detecting submerged submarines by sensitive magnetometers mounted on airplanes may prove useful in helping to find mineral deposits such as ores and oil. The devices detect extremely small irregularities in the ambient magnetic field, and such magnetic survey data in conjunction with surface geology, gravimetric, and seismic measurements tells much of the subsurface geological structure.

The problem is essentially one of detecting a small transient superimposed on a large steady or a slowly changing field. This steady field is approximately 50,000 gammas (0.5 oersteds; 1 gamma is 10^{-5} oersteds) whereas the small transients are of the order of 1 to 100 gammas.

The heart of all of the specific designs is a saturated core magnetometer. If a voltage having only odd harmonics be applied to a coil cored with ferromagnetic material, and the ambient magnetic field is zero, the current waveform will likewise contain only odd harmonics, because of the symmetry of the operating path in the B-H plane. When an external field is applied, this symmetry is destroyed, and the current waveform becomes unsymmetrical, so that even harmonics are introduced. The magnitude of any one of these even harmonic components, or their combination, is a measure of the magnitude of the ambient field that is parallel to the magnetic "axis" of the coil-core combination.

In one system developed by the Naval Ordinance Laboratory and Bell Telephone Laboratories, the magnetometer element consists of a simple coil surrounding a core of high permeability material. This coil is excited by a source whose open circuit voltage has a very low second harmonic content. The finite impedance of the source permits the even harmonics produced by the asymmetry of the core characteristic in the presence of an ambient field to appear in the terminal voltage of the coil. By means of a filter, the second harmonic component is selected, and amplified. For a fairly substantial range of field about zero, the amplitude of this harmonic is proportional to the applied field.

Bridge Circuit

In another system, developed by AIL of Columbia University, the asymmetry is observed in a different way. The magnetometer element consists of a pair of coils and cores. These, together with the balanced winding of the source coupling transformer, constitute a bridge, as shown in Fig. 1. In the presence of zero field, the bridge is balanced. Since the coils are wound in opposite sense, the voltage peak of the other coil is displaced in the opposite direction. Thus an unbalanced voltage appears across the bridge. As before, this voltage is always proportional to the magnitude of the ambient field for a considerable range about zero.

The magnetometer measures only the component of field parallel to its "axis". It is clear that, where small variations in the field intensity are to be detected, either one of two conditions must be met; an array of magnetometers whose output is independent of rotation of the array must be constructed, or the magnetometer must be maintained at a fixed angle with respect to the field direction. The former condition can be met by constructing a three element array whose elements are mutually perpendicular and by summing the squares of the outputs of the three elements. To perform such an operation with the required precision is extremely difficult. The alignment of the magnetometer elements themselves is laborious since it involves trial and error repetition. The "magnetic axis" of a magnetometer element is, in general, not easily determined from the external geometry of the element structure. The problem of producing a circuit which will have a square-law characteristic over the required range of voltage and with

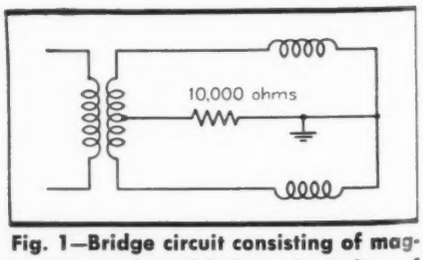


Fig. 1—Bridge circuit consisting of magnometer coils and balanced winding of coupling transformer.

the precision required is also of prohibitive difficulty. Therefore, the principal effort has been placed on stabilizing the direction of the magnetic axis of one magnetometer with respect to the direction of the field.

Three Stabilizing Systems

It is desirable to stabilize the magnetometer parallel to the ambient field and three approaches have been made to this problem of stabilization. In the ASQ-1 system, the complete array consists of the measuring magnetometer and two stabilizing magnetometers, all three being mutually perpendicular. The output signal of each of the two stabilizing magnetometers controls a servo motor, which controls the rotation of the array about one of two gimbal suspension axes. When the measuring magnetometer is parallel to the ambient field, the other two magnetometer elements are perpendicular and therefore produce no signal. The output signal of each of these stabilizing magnetometers is phase-sensitive with respect to rotation of the array and therefore may be used as as error signal for actuating the servo mechanism. Moreover, a much larger signal is obtained from the stabilizing magnetometers for a given small rotation than will appear in the measuring magnetometer. In the ASQ-1 system, emphasis was placed on refining the servo mechanism so that the system maintains its orientation within ± 6 minutes of arc for angular velocities normally encountered in aircraft maneuvers.

In the ASQ-3 system, a similar array of three mutually perpendicular magnetometers is used. In addition, the principle of adding the squares of signals obtained from the three elements is applied to reduce the requirements of the servomechanism. The requirement on parallelism of the measuring magnetometer to the field is only about ± 1 degree. By the same token, the requirements on the proportionality of the elements and the precision of the square-law circuits is much less than would be where stabilization was completely eliminated.

A third system developed by AIL of Columbia University and Sperry Gyroscope Company uses a gyroscope for most of the stabilizing action. A gyroscope mounted in a two axis suspension maintains its spin axis parallel to the ambient field in much the same manner that an artificial horizon or controlled gyroscope is maintained vertical. That is, the plane perpendicular to the ambient field is defined by two magnetometers, as was done in ASQ-1 and ASQ-3. These two magnetometers are mounted on the gyroscope case and output signals are used to control precession of the gyroscope case and output signals are used to control precession of the gyroscope. The measuring magnetometer is mounted parallel to the spin axis of the gyroscope. In an experimental model, the spin axis of the gyroscope was maintained parallel to the ambient field within ± 3 minutes of arc and, there is no limit to the angular velocity of rotation at which necessary stabilization would be effective.

With magnetometer elements of the sensitivity that are used in most of these systems, the region in which the output is proportional to the ambient field is considerably smaller than the magnitude of the earth's field. When the measuring element is parallel to the earth's field, therefore, it is necessary to introduce a biasing field that subtracts most of the earth's field, leaving the difference within the region of proportionality. Such a compensating field can readily be supplied by passing a small steady current through the winding of the magnetometer element itself. In the same manner, correction can be made for small errors in perpendicularity of the three magnetometer elements.

Electronic Drives

From a talk "Electronic Feed Drives for Milling Machines" by Mark Morgan, Reed Prentice Corp., at AIEE, April, 25, 1947, Worcester, Mass.

The main cause of heat inside the electronic motor control unit is the voltage drop across the tube and filaments of the thyratrons. The voltage drop is caused by ionization around the cathode and for any given tube is a fixed value. This depends chiefly on the type of gas or vapor present in the tube and sometimes on the temperature of operation, but is independent of plate current, size of tube, or potential of the anode.

Two types of thyratrons are commonly used: Mercury vapor tubes, and gas filled tubes that use such gas as Xenon. The average voltage drop for mercury vapor is 15 volts, the range being between a minimum of 6 and a maximum of 24 volts. For Xenon tubes the average voltage drop is around 9 volts. So for example a load of 6 d.c. amp., which is approximately that of a 1½ hp. motor at 230 volts, the heat loss from voltage drop is 90 watts for a mercury tube, but only 54 watts for a gas tube.

Heat generated by the filaments may be equal to or larger than that caused by the voltage drops; and it is present whenever power is on, regardless of whether the tube is firing and of value of plate current. For instance, commonly used thyratrons rated 6.4 amp. output have filament loss of about 50 watts in either the mercury vapor or the gas filled type.

So with other conditions equal, a unit with gas filled thyratrons will operate cooler than one equipped with mercury vapor tubes; and a half wave unit will also be somewhat cooler than a full wave or three phase unit of identical rating.

Generally, a Nema 1A, or air tight, inclosure is not suitable, unless some sort of cooling is provided, such as a blower to circulate the air within the box. If Nema 1, or an open type, inclosure is used certain precautions may be necessary to prevent fine cast iron dust from depositing itself on some of the electronic components. A fine wire mesh behind the ventilating louvres has given excellent results.

When the electronic unit is mounted on the machine, excessive temperature is not only dangerous to the electrical parts, but it may also affect the accuracy of the machine itself.

Another practical element is the space required by electronic units. The importance of this is more evident in small machines, where the units are mounted in machine compartments. Large machines often use floor mounted cabinets and space is of secondary importance.

A compact unit requires simple circuit that uses a minimum of auxiliary equipment. This in turn is accomplished by leaving out some of the features that are available in these drives but may not be strictly necessary for a satisfactory performance. This may include automatic compensation for line voltage fluctuations, quick slow-down, field loss relay, and filament circuit relay.

Especially desirable features on electronic drives generally include: ARMATURE VOLTAGE DROP COMPENSATION. This gives a flat load-speed curve so the preset speed does not vary with the

load. Drives are available where preset speed does not vary more than 1 or 2 percent from no load to full load between 10 and 100 percent of base speed. The advantage of this may not be too evident in a feed drive which is a constant torque (i.e. constant load) drive: but is useful in a constant horsepower application such as for a spindle.

DYNAMIC BRAKING FOR RAPID DECELERATION. This usually requires a study of the duty cycle of the application, because it affects the physical size of the dynamic brake resistance. For instance, a 10 ohm resistance used for braking a 1 hp. motor, can be made up in any dimension depending upon the size of the wire employed, and the size of wire should be gaged to the severeness of duty cycle.

CURRENT LIMITING CIRCUIT. This allows the motor to be started across-the-line without undergoing a current inrush higher than a preset value which can be usually adjusted between 100 to 200 percent of full load current. When selecting an electronic unit for a given application, the degree of acceleration desired should be determined so that thyratrons of suitable rating are used. If a high degree of acceleration is required, a high setting of current limit will be necessary. In this event it may be well to employ tubes of comparative large rating for the purpose of safeguarding the life of the tubes themselves. For example, a C6J Thyratron is rated at 6.4 amp. maximum continuous output. This tube is well suited for a half wave drive rated 1 hp. with current limit setting of 150 percent; or for a 1½ hp. drive with current limit setting of 100 percent. In both instances the maximum current delivered by the tube will be approximately 6 amp., and long tube life is to be expected. But if the 1½ hp. unit is set for 200 percent current limit, the steady repetition of 12 amp. peaks, superimposed on a 6 amp. average load, will shorten the useful life.

Gas Compressors

From "Survey of Leading Manufacturers of Gas Compressors," by L. P. Jehle in Final Report No. 396, Field Information Agency, Technical, PBO12610.

An investigation of the leading manufacturers in American, British and French zones in Germany revealed the follwing information on gas compressors:

1. There has been a trend toward development and production of reciprocating machines for the very high pressure range up to 3,500 atmospheres.
2. Rotary compressors for medium pressures in large volume are being made and used in considerable quantity.
3. There have been no outstanding wartime developments in reciprocating equipment for use up to several thousand pounds per square inch.
4. There has been no outstanding development in turbo compressors.

Interesting design features include:

Deutsche Maschinenfabrik A. G.

All large reciprocating compressors built by DEMAG have externally supported pistons. Pistons thus never work on the cylinder walls, the weight of the pistons being transmitted by the piston rods to accessible guides arranged in cooled bearings outside the cylinders. A supply of cooled and filtered oil scavanges and cools the bearings and larger journals. The slippers in the cross-head guides have circulating lubrication.

The only parts rubbing in the cylinder wall are the piston rings. Oil consumption is said to be small and the cylinders remain perfectly round after considerable service. In some cases DEMAG designed the piston rods to be turned on two axis slightly inclined to each other, so that they form approximately a straight line when loaded by the piston. Movable stuffing boxes may then follow the remaining slight vertical movements of the piston rod without damage. DEMAG claims that machines with floating pistons have two percent better efficiency than those with gliding pistons.

The main frames of the DEMAG machines are either of the fork or bayonet type, provided after the manner of the gas-engine frames with unilateral cross-head guides. They have broad faces the whole of the length on the foundation, or else embedded in, or firmly anchored to it. The cylinders, distance pieces and rear guides attached to the frame are supported on racking supports. The racking supports consist of strong backing-up rolls equipped at their ends with cylindrical saddles and mounted in corresponding pans. The rolls are designed to take not only the weights on the foundations, but also to follow the longitudinal movements induced by the piston pressures and expansion due to heat.

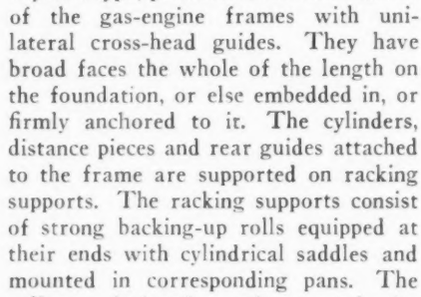


Fig. 1—KSB rotary compressor.

Cylinders of the very large machines have a separate water cooling jacket. The outer cast-iron shell has an annular slit covered with a band for sealing the water-cooling jacket. This annular slit eliminates the stresses due to heat, and the cooling jacket is always accessible. This also avoids the necessity of having chaplets welded in during the casting and which may leak.

Gutehoffnungshutte Oberhausen A. G.

Design features of interest on the turbo-compressors include the sealing between the stationary and rotating parts of the compressor, accomplished with labyrinth type seals usually constructed of bearing metal and mounted in cast iron rings. The back leakage is said to be less than 2/10 percent of the total volume of gas pumped when the radial clearance is held to the specified tolerance of not more than two thousandths of an inch. The outermost seals are liquid seals operating with either oil or water, designed so that the excess liquid is ejected tangentially from the spinning rotor into a collector system, thereby preventing contamination of the gas.

Turbo compressors are constructed either with interstage coolant or a cooled housing. In the cooled housing construction the cooling fins are mounted in separate compressor rings on the housing. Cooling water space is divided by horizontally located guide ribs. Deaeriation is provided for at the highest point of the section. The cooling water is force-circulated. The coolant is delivered to the individual rings

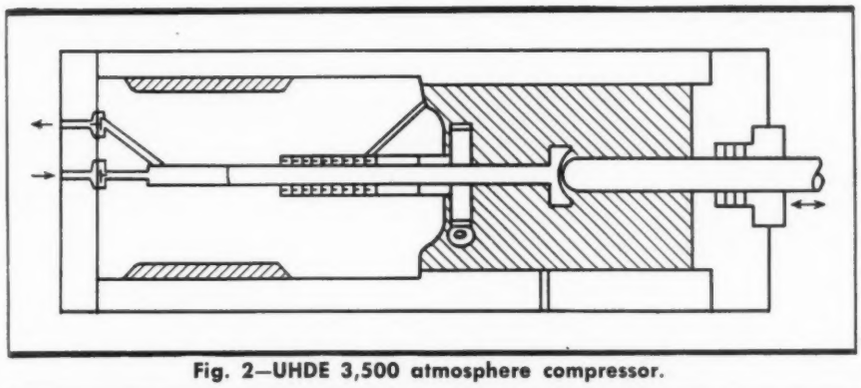


Fig. 2—UHDE 3,500 atmosphere compressor.

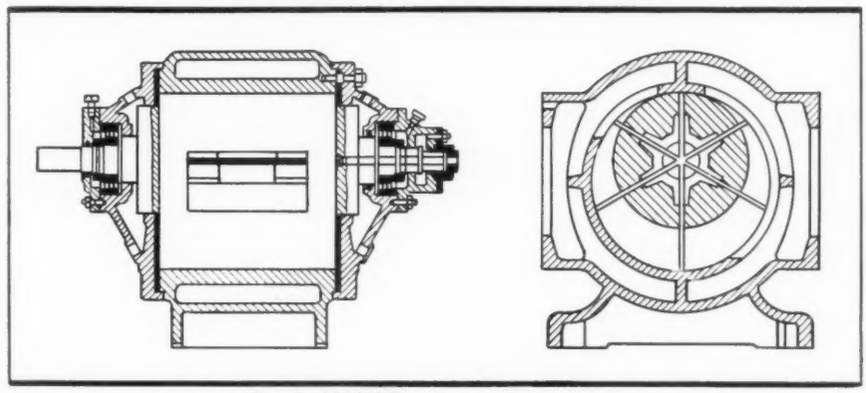


Fig 3—MAPAG rotary compressor.

by special distributing tubes inclosed through adjacent rings in opposite direction in order to insure complete thermal uniformity.

Klein, Schanzlin & Becker, A. G.

KSB manufactures an interesting rotary compressor with suction capacities from 300 to 4,000 cu. m. per hr. The single stage machine would deliver up to two atmospheres pressure, the two-stage unit up to eight atmospheres. These compressors are extensively used for driving airpressure tools of all kinds. Rotary compressors are claimed to have the advantage of being capable of direct-coupling to high-speed electric motors. They are said to be practically vibration free and require only light foundations. Installation space requirements are low, and maintenance is simple.

KSB uses a revolving drum supported on roller bearings mounted eccentrically in a water-cooled housing, forming a crescent-shaped working space. This space is divided into cells by freely movable vanes mounted in slots in the drum. The vanes are forced out of the drum slots by centrifugal force and pressed against runner rings at both ends of the housing. The outer diameter of the runner rings is slightly less than the housing bore, which therefore, rotates with the vanes. The runner rings are positioned in the housing and are incapable of radial displacement. The runner ring bearing absorbs the tangential loadings developed during operation. The housing wall therefore takes none of the direct friction of the working vanes. It is claimed that runner ring and runner ring bearing feature of the KSB design is responsible for the long life and low oil consumption of the compressor. Highest recommended rotational speed is 1,450 r.p.m. The KSB one-stage rotor compressor is illustrated in Fig. 1.

UHDE Gesellschaft fur Hochdrucktechnik

UHDE has developed reciprocating compressors to deliver hydrogen at 3,500 atmospheres pressure. Suction pressures are 300 atmospheres. Hydrogen at capacity of 100 liters per hour is compressed in a single stage to 3,500 atmospheres.

The piston is a ringless plunger 5/8 in. in dia., about 1 ft. long and made from a nickel-alloy steel. The stroke is about 4 in. UHDE claims that the successful performance of this extreme pressure compressor depends largely on the excellence of the fit between the plunger and cylinder wall. Both are ground and hand-fitted to a radial tolerance of several ten thousandths of an inch. The packings are made of bronze with a special self-interlocking U-shaped cross section. Total length of the bronze ring packings was about 3 in. Packings were secured and compressed around the plunger by a retaining ring which had gear teeth cut into its exterior profile. These meshed with a worm-gear drive so that it was possible to tighten the packings while the compresor was in operation.

Another reason for the worm-gear drive mechanism for pulling down on the plunger packing was because the driven end of the plunger was sealed in a forced feed oil circulating system at 300 atmospheres pressure. This necessitated a remote control device for adjusting plunger packings. The surface of the plunger was lubricated by means of forcing oil into the bronze sealing ring chamber as well as the chamber surrounding the driven end of the plunger. Fig. 2 gives the essential features of this compressor in a schematic.

Maschinenfabrik Surth A. G.

Of greatest interest mechanically is the heremetically-sealed compressor used in refrigeration installations. The need for shaft seals is obviated because motor and compressor operate in the refrigerant atmosphere. As the rotor turns, the pistons are thrown outward by centrifugal force. An eccentric slip ring forces the piston back towards the shaft, thereby creating pumping action.

Maschinenfabrik Augsburg-Platting A. G. (MAPAG)

MAPAG's rotary compressor consists of an eccentrically-mounted rotor *B* which rotates in the housing *A*. Radial vanes pass completely through the rotor and compartmentalize the swept-out volume. The compartments are sealed with a plastic-composition material. The compressor is illustrated in Fig. 3. Novel features of this compressor are first that the inner cylindrical surface of the housing against which the vanes rub is a cylindrical liner made from a filled-phenol formaldehyde plastic composition; secondly, the lubrication between the vanes and the plastic cylindrical liner is either water or a water-soap emulsion. The water is forced into the compressor through a hole in the axis of the shaft and is recirculated by means of exterior sump and cooling systems.

The compressor is direct-driven by an electrical motor, because the operating speed ranges between 1,450 to 2,900 r.p.m. Maximum delivery of a single stage machine is about four atmospheres. Aside from the advantage of relative cheapness due to simple construction, this compressor's main advantage is that it will deliver compressed gas entirely free of oil. Wear on the plastic composition liner over a five-year period has been negligible.

Centrifugal Governor Speed Control For SMALL MOTORS

W. M. YOGERST
Bodine Electric Company

Preset and adjustable types of centrifugal governors discussed. Various constructions, basic control circuit, and some typical motor operating characteristics are included.

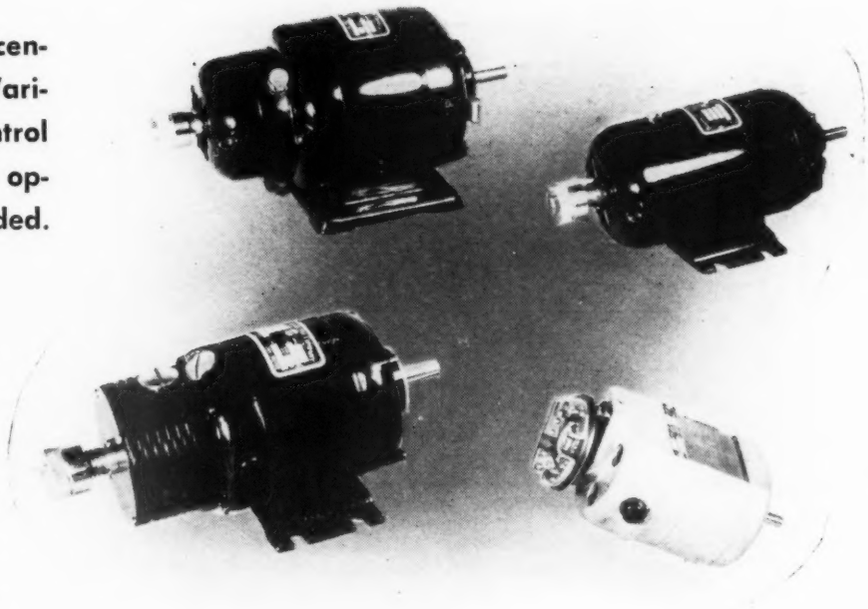


Fig. 1—Turning knob on left end of the three black motors adjusts speed while motor is running. The white motor, on right, has a preset type of regulator.

FOR CERTAIN fractional horsepower motor applications electric governors are the best solution for speed control problems. This is often true for series wound motors, such as shown in Fig. 1, and occasionally for shunt motors.

The electric governor is a centrifugally operated switch that automatically reduces the current through the motor when the motor runs faster than the speed for which the governor is set. Similarly, when the speed falls below the setting the governor restores full line voltage to the motor. A typical connection diagram is shown in Fig. 2 for a series wound governor controlled motor.

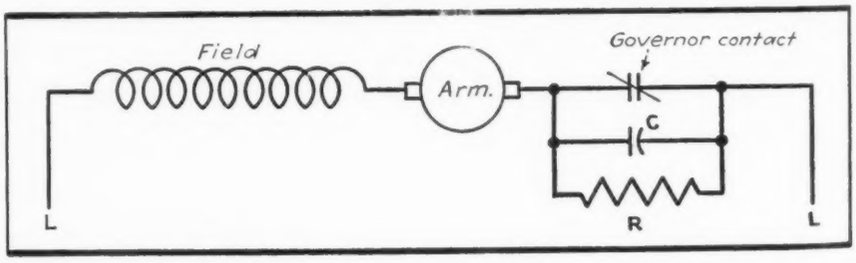


Fig. 2—Connection diagram for series wound governor controlled motor.

The two types of electric governors in common use are shown in Fig. 3. One can be adjusted over a narrow speed range while at rest, the other can be adjusted over a wide speed range during rotation. The performance of electric governor controlled motors are superior to rheostat controlled motors because they maintain full torque at all speeds, while use of rheostats reduce starting torque and stability at low speeds. But a disadvantage is that the added brush friction on the governor collector rings places a considerable additional load on the motor, especially at high speeds. For a given size this leaves less power at the drive shaft of a governor controlled motor than for a series wound motor without a governor.

The construction of the electric governor is such that the two contact points, separately mounted, touch each other and are connected in series with the motor windings. Centrifugal force acting on one of the spring biased contacts and its supporting arms tends to separate the contacts and interrupt the current flow. The contact points are manually adjusted so they can be preset to open at different speeds of the motor.

If the governor were to interrupt the current completely, the speed of the loaded motor would drop suddenly causing the governor contacts to close and restore the full current supply. Operating under the extremes of no current and full current, the motor would run in a jerky manner. Furthermore, making and breaking the full current would burn the contact points. Therefore, a resistor is shunted across the contact points so when they open the current to the motor is merely decreased instead of being completely interrupted.

A condenser is usually connected across the governor contacts to further reduce the spark when the con-

tacts open and close. After the proper size of shunt resistance has been selected and installed, the required capacity of the condenser is determined by test under working conditions. The condenser capacity should be of the lowest value compatible with minimum sparking at the contact points.

When operating, the governor controlled motor tends to run faster than the speed for which the governor is set, thereby causing the contacts to open and compelling the current to flow through the resistance. This causes the motor speed to drop. The contacts then close, normal operating voltage is restored, and the motor speeds up until centrifugal force again opens the contacts. With the motor and governor correctly designed for the application and the by-pass resistor carefully chosen, this action is extremely rapid and there is no noticeable change in motor speed.

The motor operates in effect as two motors, one weaker than the other, having different speed-torque curves. The weaker of the two motors, the one operating when the switch contacts are open and the resistance in the circuit, is not quite powerful enough to operate the load at its point of minimum torque requirement at the desired speed for which the governor is set. The second motor is more powerful than the first, and is strong enough to operate the load at its maximum torque requirement but at a speed in excess of that desired. Thus, the governor transfers the load rapidly from one motor to the other, so rapidly, in fact, that the speed has not time to reach a constant value for either of the two motors, but as shown in Fig. 4 is kept at some average range for which the governor is set.

The proper value of resistance to be put across the governor contacts can be determined only when both the maximum and minimum value of torque required and the range over which the governor is to operate are known. If these factors are not known, the motor engineer recommends a relatively high value of resistance to prevent runaway speeds at light loads. This may not permit the appliance manufacturer to secure the torque range desired on high speeds, nor to secure the range of speeds needed. Similarly, the motor engineer must determine from the data submitted to him just which type of motor winding will serve best to cover the speed and torque range specified and permit minimum current to flow through the contact points.

A governor controlled motor designed to operate over a speed range of 2,000 to 7,000 r.p.m. requires a much more powerful initial winding than one that is to operate over a range of 2,000 to 4,000 r.p.m. Motors having the wider speed range will also be larger than motors operating over the narrower speed rang,e unless the torque requirements are extremely light. At speeds below 2,000 r.p.m. the motor will operate in a somewhat jerky fashion. The most sensitive governor action is obtained when the range between maximum and minimum speed is the smallest possible.

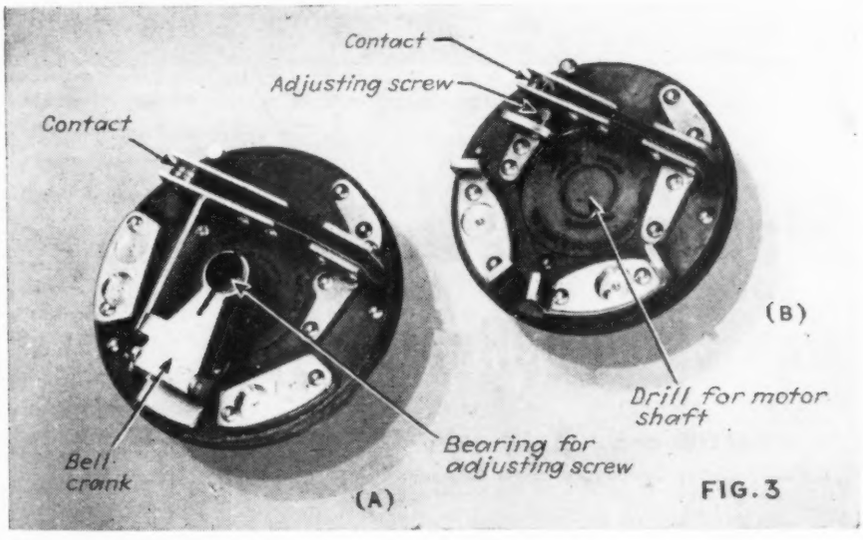


FIG. 3

Fig. 3—Centrifugal type electric governors. (A) Speed adjustable while motor is running; (B) speed is preset by adjusting screw with motor stopped.

Fig. 4—Typical operating characteristic of governor controlled series motor.

Fig. 5—Speed of governor controlled motor is adjustable throughout entire range while driving surgical engine.

V. Mueller and Company

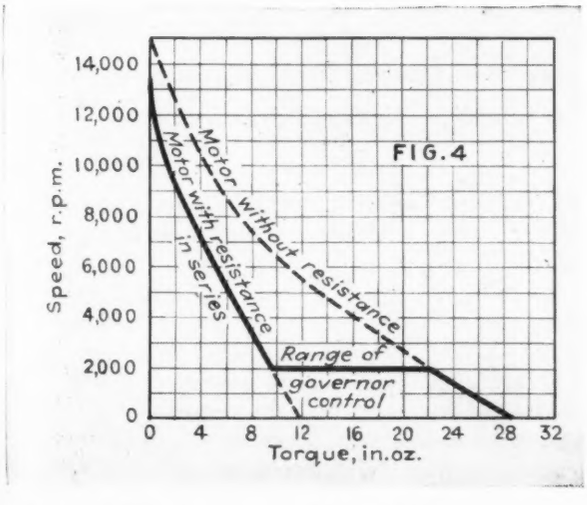


FIG. 4

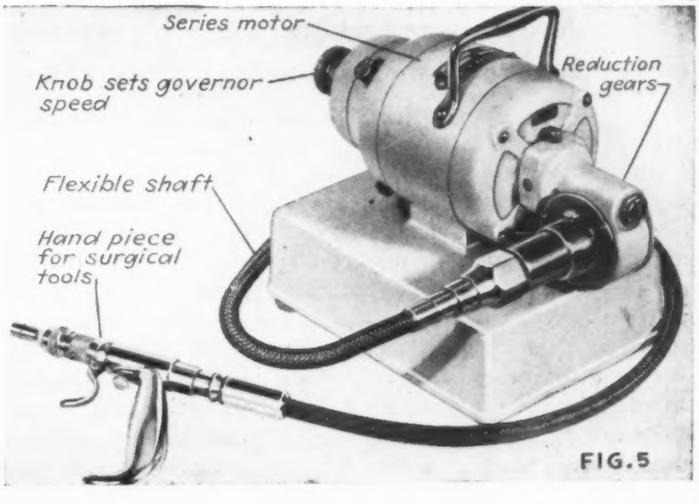


FIG. 5

Westinghouse Electric Corporation

Fig. 1—Melamine laminate sheets can be fabricated into products of intricate shape, and in a wide variety of sizes.

Urea and Melamine Resin Products

Properties and Applications

M. H. BIGELOW and J. A. MURRAY
Plaskon Division, Libbey-Owens-Ford Glass Company

Properties of thermosetting urea and melamine plastics include good water resistance and hardness, as well as moldability in a wide range of colors. In addition to molded products, applications include laminates, adhesives, coatings and insulation. Production techniques and design factors are covered.

CAPABLE of being molded in a wide range of colors, urea and melamine resins form thermosetting plastics that are tough, hard and water-resistant. Pure urea-formaldehyde resins are colorless. Fillers, usually alpha cellulose pulp, are incorporated to improve water resistance and prevent cracking and crazing. The resulting compound is translucent and by adding proper pigments, can be produced in an unlimited range of opaque colors.

Melamine-formaldehyde, like urea-formaldehyde, is an "aminoplast", which means that it is made from nitrogen-containing base materials. In appearance and many properties, melamine is similar to urea. Its higher cost, however, is offset by superior resistance to high temperatures, compatibility with mineral fillers and increased resistance to water.

In choosing the proper type of molding compound, there are many factors to be considered: Size and shape of the piece to be molded, length of draw, and pressure available. With so many variables, no one compound is satisfactory for all molded parts.

Urea-formaldehyde molding pow-

ders are produced in three standard plasticities designated as Standard Medium, Soft and Extra Soft. Melamine-formaldehyde powders are available in Standard Medium and Special Soft forms. A brief description of the fields of application of each standard type follows:

STANDARD MEDIUM. This is the most widely used type of urea and melamine. It is suitable for almost all castings, from small parts to larger moldings such as clock cases and similar housings. This type can be used for all moldings except those of extremely long draw, intricate design or those for which insufficient pressure is available. Standard Medium is generally molded at 300 to 320 deg. F,. and is relatively free of gas.

SOFT. This type is appreciably softer than Standard Medium, remains in a plastic condition longer and cures at a somewhat slower rate. Soft compound is generally used in jobs for which Standard Medium would be used were sufficient pressure available. Since the cure is slightly slower, Soft will fill out castings more completely under low pressures before setting up. Soft is molded at temperatures of 280 to 300 deg. F.

EXTRA SOFT. This type is even softer than Soft type and cures somewhat less rapidly. It is usually molded at temperatures between 280 deg. F. and 300 deg. F. Extra Soft is not recommended for universal use but can be molded into such pieces as large reflector bowls with long draws, or other simple but large castings for which full pressure is not available.

SPECIAL SOFT. This melamine compound is required for molding jobs where sufficient pressure is not available to use Standard Medium melamine—formaldehyde, although it cures at the same rate.

Molding Techniques

Urea and melamine plastics are molded by compression molding, and by transfer molding, a variation of compression molding which is suitable where fragile inserts, high dimensional accuracy and low original mold cost are design factors. When the transfer molding, for these reasons, is desirable, a plunger type mold, one in which mold closing pressure and molding pressure are independent, is recommended. The use of radio frequency preheating and rather high pressure are also recommended. (See article in PRODUCT ENGINEERING, November, 1946, page 129.) In Table I molding characteristics of urea and melamine plastics, containing various fillers, are shown.

Type of mold construction, degree of cure, and distribution of effective molding pressure influence the properties of the final molded part. Moldings of excellent appearance and quality are produced in every type of compression mold, from "full flash" to "full positive". Best results are obtained with techniques that allow the material to flow under adequate continuous pressure and keep it well sealed in the mold throughout the cure cycle.

Flash lines of the fundamental types of compression molds are shown in Fig. 2. Flash molds, Fig. 2(*A*), are satisfactory for pieces of simple design and shape, where sufficient loading capacity is available. This type of mold has been successfully used in making such parts as small containers, wall plates and small housings.

Flash molds with guiding or loading wells, Fig. 2(*B*), are sometimes called semi-positive, but they are merely flash molds with the advantages of additional loading capacity and guiding action. They have been satisfactorily used in the molding of such pieces as boxes, packaging items, lamp shades and reflectors, stove and refrigerator handles, drawer pulls, knobs, tableware, housings, and electrical and wiring devices.

In semi-positive molds, Fig. 2(*C*), the material is put under positive pressure a short time before the mold is closed. This serves to equalize uneven flow conditions and give maximum density to the piece. This type of mold has been successfully used for the molding of pieces in which heavy section of intricate flow conditions are involved, such as radio cabinets, scale housings and other parts of complicated design.

The positive mold, Fig. 2(*D*) is rarely used today in the molding of urea and melamine resins.

Proper Taper for Long Draw

In molding large housings, or similar castings of deep draw, best results are obtained by using not only semi-positive dies, but also the principle of decreasing taper of side wall sections.

This principle is illustrated in Figs. 3 and 4, showing proper, or decreasing, and improper, or increasing sidewall taper. In molding the piece shown in Fig. 3, the compound becomes increasingly tightly confined, through a kind of wedging action, as it flows vertically up the side wall. Hence the effective pressure, so important in molding urea and mela-

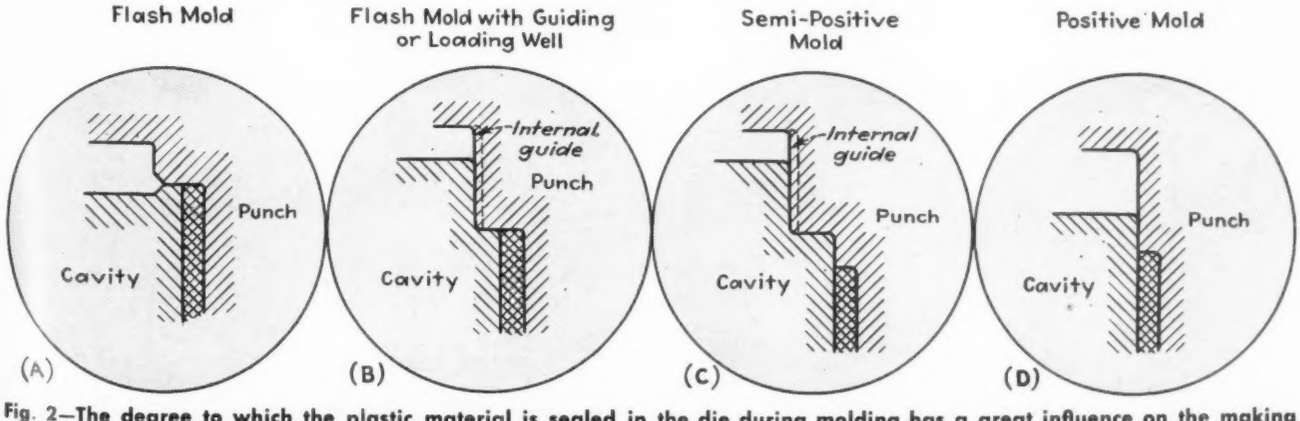


Fig. 2—The degree to which the plastic material is sealed in the die during molding has a great influence on the making of good pieces, since it determines actual pressure in the die. Thus, the least satisfactory is the loose fitting positive type.

Table I—Properties of Molded Urea and Melamine Plastics

Property	ASTM Method	Urea, Cellulose Filled	Melamine		
			Cellulose Filled	Asbestos Filled	Macerated Fabric Filled
Molding quality	.....	excellent	excellent	good	good
Molding temperature, deg. F	.....	290–325	280–340	280–340	275–340
Molding pressure, lb. per sq. in.	.....	1500–6000	1500–6000	1000–7000	3000–5000
Compression ratio	.....	2.2–3.0	2.0–2.7	2.1–2.5	5–10
Colors	.....	unlimited	unlimited	dark colors	limited
Specific gravity	.....	1.45–1.55	1.45–1.55	1.70–2.00	1.40–1.45
Tensile strength, lb. per sq. in.	D48–43T	8,000–13,000	8,000–13,000	5,500–7,000	7,000–8,000
Compressure strength, lb. per sq. in.	D649–42T	25,000–35,000	25,000–35,000	30,000	26,000–32,000
Flexural strength, lb. per sq. in.	D650–42T	10,000–16,000	10,000–16,000	9,000–11,000	10,500–15,000
Impact strength, Izod, ft.-lb. per in.	D256–43T	0.24–0.35	0.24–0.35	0.28–0.40	0.5–0.8
Hardness, Rockwell	D785–44T	M118–M122	M118–M122	M112	.....
Heat resistance, continuous, deg. F	.....	170	210	250–380	250
Heat distortion, deg. F	D648–45T	270	300	266	310
Water absorption, 24 hr., percent	D570–42T	0.5–0.7	0.4–0.6	0.08–0.14	0.3–0.6
Water absorption, 1 week, percent	.....	2.4–2.8	1.7–2.1	.....	.....
Dielectric strength, short time, volts per mil	D149–40T	300–400	300–400	350–450	250–350
Volume resistivity, ohm-cm	D257–38	10^{12}–10^{13}	10^{12}–10^{13}	10^{11}	.....
Surface resistivity, ohms	.....	4 x 10^{11}	4 x 10^{11}	10^{11}	.....
Dielectric constant, 60 cycles	D150–41	7.0–9.5	7.5–8.3	6.4–9.9	.....
Dielectric constant, 1,000,000 cycles	D150–41T	6.4–6.8	7.4–8.2	3.5–7.6	6.7
Power factor, 60 cycles	D150–41T	0.039–0.041	0.037–0.080	0.07–0.17	.....
Power factor, 1,000,000 cycles	D150–41T	0.029–0.032	0.043–0.045	0.04	.....
Arc resistance, sec	D495–41T	140–145	140–180	120–140	.....

mine, is maintained throughout the flow of the material.

When a casting designed with increasing taper of the sidewall, Fig. 4, is molded, the compound is allowed increasing freedom as it flows vertically up the sidewall. The material is not under effective pressure, as it is in a sense being extruded from a small orifice into a relatively unconfining chamber.

The importance of the principle of decreasing taper with flow can be illustrated in the molding of a small radio housing of symmetrical design, 10 x 8 x 6 in. deep. Such a cabinet with decreasing taper wall section, as in Fig. 3, can be molded satisfactorily even in a flash type die, and with no difficulty in a semi-positive die. With an increasing taper wall section as in Fig. 4, however, the same cabinet is almost impossible to mold in a flash type die, and is even difficult to mold in a semi-positive die.

Properties and Design Factors

Urea and melamine plastics are, for most applications, strong and durable. They have high surface luster, which is unaffected by handling. They are resistant to oils, greases and organic solvents. Water resistance of melamines is superior to ureas. Being organic compounds, urea and melamine plastics will decompose if heated to high temperatures. Nevertheless, they may be used at relatively high temperatures for short periods of time. Melamines, however, can withstand higher temperatures than urea plastics. Where temperatures are excessively high, the design of the piece can be altered to meet the conditions. As shown in Fig. 5, this is particularly true for lighting fixtures. Physical properties of urea and melamine plastics are given in Table I.

When designing parts to be molded of melamine and urea resins, certain principles should be kept in mind, the observance of which make for ease and economy of production.

The piece must be easily removed from the mold. Since the motion of the die is up and down, deep undercuts, re-entrant curves, or side holes can only be obtained with expensive split molds, or retractable pins.

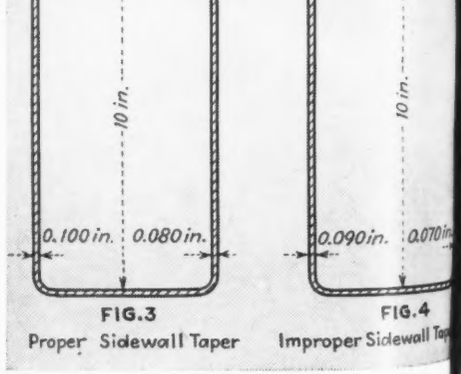
Abrupt changes in wall section should be avoided, and when difference in section is necessary, the difference should be held to a minimum.

Sections heavier than $\frac{1}{2}$ x $\frac{1}{2}$ in. are not recommended, because of the slow cure cycles required, and the corresponding danger of porosity and undercure at the center of the section. This limitation is often overcome—as in gear knobs—by assembling two hollow sections, with economy both in material and molding speed.

Increasing the section of a urea or melamine molding does not increase the strength proportionately. Hence a thin wall section is generally preferable to a thick one, and makes for economy both in material and speed of productoin.

When flat shapes are contemplated it is best, when possible, to curve the surface to some extent in both planes, thus providnig for at least a partial flow of material in molding, resulting in a stronger piece.

The monotony of large flat surfaces may be broken up with pleasing effect



Figs. 3 and 4—Proper and improper tapers for long draw urea and melamine moldings.

by ribbing or fluting, or by curving and doming the surface to concentrate the highlights.

Sharp, square corners and edges should be avoided. Not only do they increase the cost of the die and impede the flow of the plastic mass in molding, but such corners on a molded piece are subject to chipping. A full rounded edge and inside fillets should be used whenever possible.

It is always preferable to have the parting line on an edge rather than on a rounded surface. Not only does this simplify the molding, but it also reduces the finishing cost.

When bosses are desirable on the inside of such housings as radio cabinets and clock cases, they should be placed at the inside corners, rather than in the middle, where they increase the danger of color streaking on the outer surface.

Long, thin protuberances from the body of a molding should be avoided, since they are easily broken and difficult to mold.

It is advisable to allow for a somewhat thinner section at the top of the "draw" than at the base, such as in a radio housing.

Inserts are readily molded securely into place, but a shell of material sufficiently thick should be molded around them to prevent cracking resulting from the difference in coefficients of expansion between metal and plastic.

Urea and melamine are not recommended for complicated machining operations, but simple operations of tapping and drilling can be easily and safely performed. Whenever possible, these materials should be molded in the desired form, resulting in the need for a simple defining and finishing operation, done in tumbling barrels.

Non-Molded Applications

LAMINATES. Curved surfaces using various fabrics such as cotton duck and glass cloth and a binder such as modified urea—formaldehyde and the newer "contact" resins have been produced. The processes used require relatively low pressures. Initial mold costs are low—wood, concrete or plaster can be used. Although a large number of aeroplane pilot seats, for example, were made by this method, the process is in general restricted to low volume items because of the cost and great amount of skilled hand labor necessary in laying up the assemblies, and in subsequent operations.

Flat laminates, however, lend themselves to mass production using high pressure methods. Melamine laminates, Fig. 1, offer a combination of high strength and valuable electrical properties. The properties of melamine laminates when paper, asbestos, and glass fiber are used as a base are shown in Table II. Melamine resins have the advantage over phenolic resins of being water white and lightfast. This property makes it advantageous to use them in decorative laminates. Melamine resins impregnated paper and fabric are also used as decorative overlays for phenolic laminates and plywood. The incorporation of a metallic foil directly under the overlay makes the laminate highly resistant to marring by heat. The wide color and decorative possibilities of melamine laminates are being recognized.

INSULATION. When an aqueous solution of urea resin is rapidly stirred in the presence of a small amount of foaming agent and hardener, a light

Table II—Properties of Melamine Laminates

Property	Paper Base	Asbestos Base	Glass Fiber
Laminating temp., deg. F	290–320	290–320	300–320
Laminating pressure, lb. per sq. in.	1000–3000	1,000–3,000	1,000–3,000
Specific gravity	1.45–1.55	1.75–1.85	1.90–1.95
Tensile strength, lb. per sq. in.	10,000–25,000	6,500–12,000	16,000–29,000
Compressive strength, lb. per sq. in.	30,000–48,000	27,000–47,000	30,000–97,000
Flexural strength, lb. per sq. in	20,000–36,000	17,000–24,000	34,000–44,000
Impact, Izod, ft.-lb. per in.	0.3–1.5	0.75–1.5	10–12
Hardness, Rockwell	M115	M115	M110
Resistance to heat, continuous, deg. F.	210–260	225–245	225–245
Dielectric strength, short time, volts per mil.	400–700	100–150	490–520
Dielectric constant, 1,000,000 cycles	6.7–8.5	8.0–9.6	6.9–7.5
Power factor, 1,000,000 cycles	0.03–0.04	0.12–0.22	0.011–0.013
Water absorption, 24 hr., percent	1.0–4.6	1.0–4.2	0.7–3.5

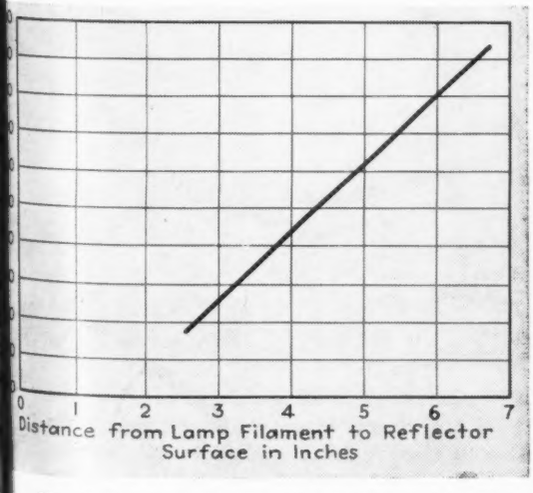


Fig. 5—Lamp position and wattage for semi-indirect luminaires for 165 deg. F. operation.

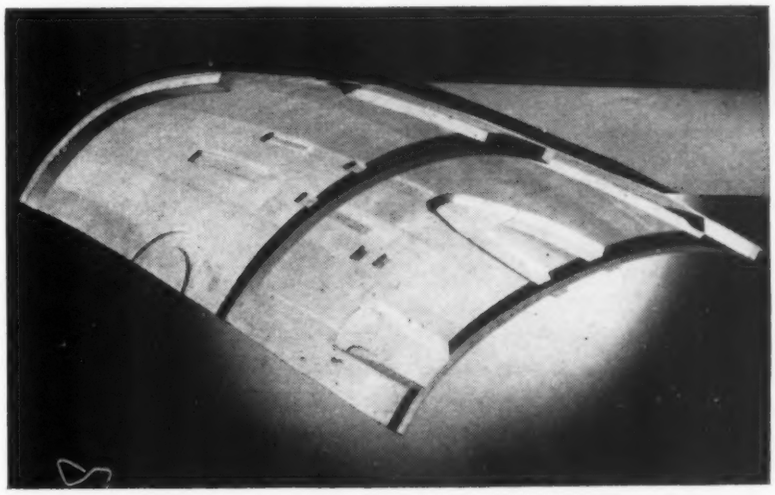


Fig. 6—Formed plywood aircraft engine nacelle bonded with waterproof urea resin adhesives, made by Universal Molded Products Co.

weight, rigid form is produced. This material has unique sound proofing qualities. For normal temperature ranges, with an upper limit of 180 deg. F., it is an excellent thermal insulator. The density of the finished material is 0.83 lb. per cu. ft. The heat conductivity is 0.23 B.t.u. per sq. ft. per hr. per deg. F. per in. Sound absorption (Box Method) is:

Sound Absorbed By Foamed Urea Resin

Thickness, in.	¾	1	1½
Frequency, cycles/sec.			
256	27	30	41
512	48	53	75
1024	80	90	80

Other expanded products are cellular cellulose acetate and honeycomb core of either paper or glass fiber. Any of these materials make good cores for insulating wall panels. Such a panel can be faced with plywood or a decorative melamine laminate. A melamine impregnated paper overlay for a plywood-expanded resin sandwich is especially useful as wall-panels, where washing is desirable. Other possibililties of using plywood or decorative melamine laminates in conjunction with expanded resin insulating materials are panels for automobiles, buses, and aircraft.

COATINGS. Urea resins are standard components of coating compounds. Urea resins compounded with alkyds, processed oils, and plasticizers form coatings that are hard, weatherproof and durable. Urea resins for this purpose are especially prepared and are available as 40 to 60 percent solution in organic solvents such as xylol, butyl alcohol and hydrogenated naphthas. These coatings compounds are thermosetting, and are usually baked at temperatures from 225 to 325 deg. F. Such coatings are suitable for automobile bodies, washing machines and similar domestic appliances. Since urea coatings do not discolor on aging they are excellent for finishing metal lighting fixtures.

Urea resins, modified with treated oils, are used to coat textiles, leather, artificial leather, paper and other fabrics. They make durable wall and floor

Table III—Properties of Urea and Melamine Adhesives

Material	Curing Temp., deg. F.	Solvent	Resistance to					Advantages
			Water	Solvents	Heat	Cold	Fungus	
Urea-formaldehyde	70–80	water	moderate to good	excellent	moderate	excellent	excellent	ease of application, non-staining
	275–310							
Melamine—formaldehyde	150–200	water	good to excellent	excellent	excellent	excellent	excellent	water resistant, non-staining
	275–310							
Urea-melamine—formaldehyde	150–200	water	good	excellent	good	excellent	excellent	improved water resistance, over urea alone
	275–310							

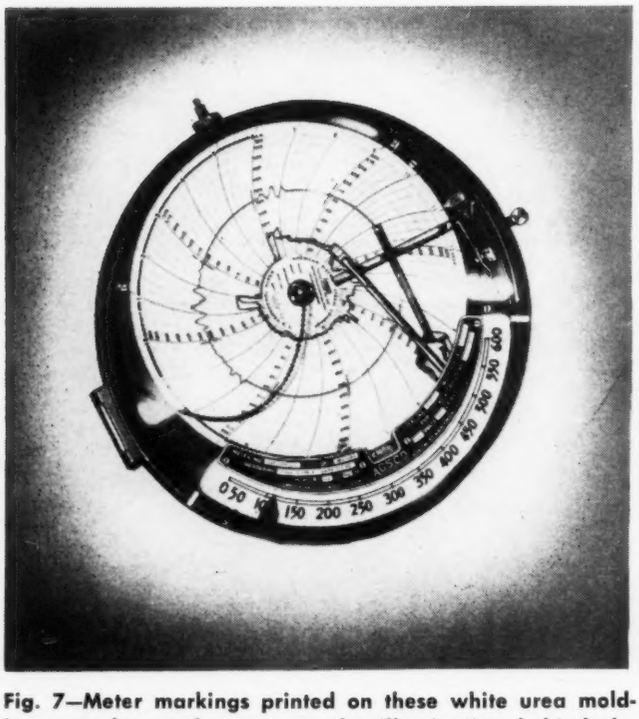


Fig. 7—Meter markings printed on these white urea moldings can be easily seen, as the illumination behind the translucent part makes the markings glow brightly. Free from warpage, urea scale on this steam pressure recorder is molded for the American District Steam Company, North Tonawanda, New York, by Dimco Plastics, Dayton, Ohio.

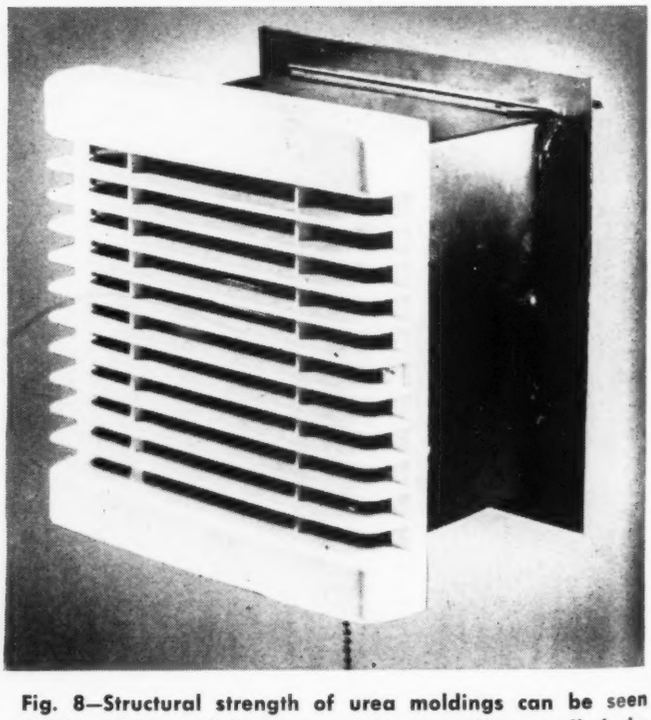


Fig. 8—Structural strength of urea moldings can be seen in this white grill for a new home ventilator, called the "Aeropel." It has a smooth finish and high resistance to chemical attack and organic solvents, making it useful in the kitchen. Manufacturing economies were possible because it can be molded in one piece and requires little finishing.

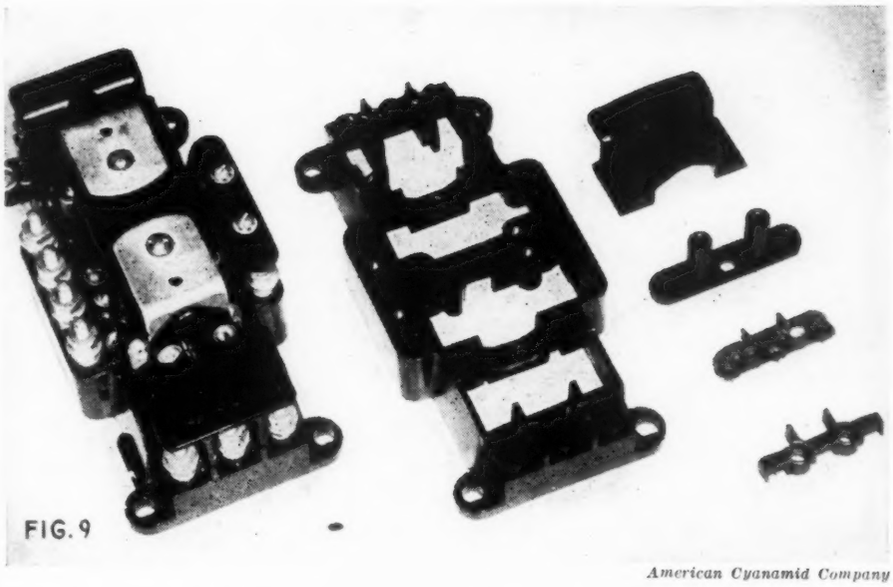


FIG. 9

American Cyanamid Company

Fig. 9—These triple-pole, double-throw motor controls carry five amperes. Contact carrier terminal covers and base, shown at right, are molded of chopped cotton-filled, melamine - formaldehyde plastic. These parts have excellent shock-resistance and arc-resistance.

Fig. 10—Speed regulators, brush-holders, bushings and washers are made from mineral filled melamine-formaldehyde plastic. These insulating parts are subject to accumulations of carbon, oil and dust, which serve as conductors for electric arcs that can burn a conducting path.

FIG. 10

American Cyanamid Company

Fig. 11—The red-colored melamine door on this alarm, which indicates tempeature rise on power transformers, makes it suitable for conditions found in outdoor use.

FIG. 11

coverings, which are proof against fire, solvents, water, and scuffing.

Melamine resins are used similarly to urea resins in coatings. They give products that are considered superior to urea resins with respect to temperature and exterior durability. They are applied in the same manner as ureas.

ADHESIVES. Urea and melamine resins are the basis of a wide variety of waterproof adhesives. There are two major types of urea adhesives, cold setting and heat setting. Melamine and melamine-urea resins require some heating. These adhesives are sold as one-part and two-part glues. In the two-part glues the catalyst or hardener is a separate item that must be mixed into the glue batch by the purchaser. Urea and melamine resin glues are used primarily for bonding wood and veneers. They are not recommended for gluing metals or other non-porous surfaces together. Melamine glues are superior to urea glues only with respect to resistance to water at elevated temperatures. Table III shows properties of these adhesives.

MELAMINE-UREA RESINS. Glue specifications such as AN-NN-5111b for formed aircraft plywood requires that the plywood withstand a three hour immersion in boiling water. Following this treatment, the requirements of the specifications are that the plywood have the quality of phenolic joints. Phenolic glues must be cured at 280 to 300 deg. F., and because of their fusibility, and amber to red color, sometimes stain veneers.

To meet this difficulty, melamine-urea formaldehyde mixtures have been developed by the American Cyanamid Company. These resins are clear, or the color of the wood flour filler. Temperatures as low as 105 to 125 deg. F. can be used for curing certain of the mixtures. Others cure at 220 to 260 deg. F. By addition of ammonium chloride catalyst, certain of the mixtures can be cured at room temperatures.

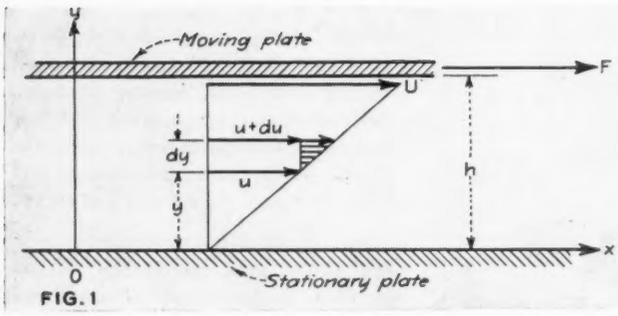


FIG. 1

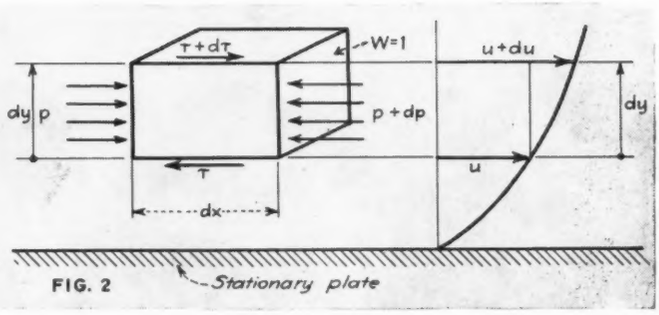


FIG. 2

Fig. 1—Distribution of fluid velocity in Couette flow between two parallel plane plates, one of which is moving and the other stationary. Fig. 2—Shear stresses resulting from pressure difference on a fluid particle in Poiseuille flow.

Friction Loss and Heat Balance In Viscous Flow Between Plates

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Fluid flow formulas are derived from Newton's viscosity law and are presented in tabular form for ready reference use in solving fluid flow problems. Also a discussion of the mutual relationship that exists between the viscosity of the fluid and the heating caused by dissipation of energy in viscous laminar flow.

THE friction law for laminar flow of fluids was first enunciated by Sir Isaac Newton in the second edition of "Principia Mathematica". This law states that the frictional forces in a fluid depend upon the relative velocities of adjacent layers of fluid. The differential expression of this statement is

$$\tau = \mu \frac{du}{dy} \qquad (1)$$

and means that the shearing stress τ between adjacent layers of the laminar flow is proportional to the change of velocity du/dy from layer to layer. The factor μ is called the coefficient of dynamic viscosity and depends upon the fluid and its state.

The limitations of this law are implicit in its statement, which speaks of parts of fluid separated from each other and, therefore, implies laminar or viscous flow.

Turbulence, which occurs when the shearing stress is small in comparison with the inertial forces arising from slight disturbances in the flow (as for instance at Reynolds numbers greater than 2,000 to 2,300 in circular pipes), will be excluded from this discussion.

COUETTE FLOW. The simplest example to which Newton's viscosity law applies is the motion of a fluid between two flat parallel plates, one of which moves parallel to the other, Fig. 1. Couette, a French physicist, investigated this case by experimenting with two coaxial cylinders having a narrow annular gap between them filled with liquids of different viscosities. The width of the gap was small in comparison with the radii of the cylindrical surfaces, so that for all practical purposes the arrangement was equivalent to two parallel plane plates of infinite dimensions.

If the lower one of these plates is held stationary and the upper one is moved with a velocity U, ft. per sec., a resistance to the displacement is experienced that is proportional to the velocity U and inversely proportional to the distance h by which the two plates are separated. This observation can be interpreted in terms of Newton's differential expression if two additional experimental facts are recognized: (1) That the fluid in contact with either plate adheres to it and stays at rest relative to it, and (2) that the change of velocity between the plates is linear. The velocity u of the fluid at any distance y from the lower plate is

$$\frac{u}{y} = \frac{U}{h} = \frac{du}{dy} \qquad (2)$$

The resistance force per unit area encountered in moving the top plate is equal to the shearing stress. Combining Equations (1) and (2) gives an expression for the shearing stress that is in agreement with experimental data,

$$\tau = \mu \frac{du}{dy} = \mu \frac{U}{h} \qquad (3)$$

The dimensions of the proportion-

Table I—Conversion Factors For Dynamic Viscosity

To Obtain \ Multiply by	Poise $\left[\frac{\text{gm. mass}}{\text{cm.-sec.}}\right]$ or $\left[\frac{\text{dyne-sec.}}{\text{cm.}^2}\right]$	Centipoise $\left[\frac{\text{gm. mass}}{\text{cm.-sec.}}\right]$ or $\left[\frac{\text{dyne-sec.}}{\text{cm.}^2}\right]$	$\left[\frac{\text{slugs}}{\text{ft.-sec.}}\right]$ or $\left[\frac{\text{lb.force-sec.}}{\text{ft.}^2}\right]$	Reyns $\left[\frac{\text{slugs}}{\text{in.-sec.}}\right]$ or $\left[\frac{\text{lb.force-sec.}}{\text{in.}^2}\right]$	$\left[\frac{\text{lb. mass}}{\text{ft.-sec.}}\right]$ or $\left[\frac{\text{pdl.-sec.}}{\text{ft.}^2}\right]$
Poise $\left[\frac{\text{gm.mass}}{\text{cm.-sec.}}\right]$ or $\left[\frac{\text{dyne-sec.}}{\text{cm.}^2}\right]$	1	0.01	478.8	6.895×10^{4}	14.88
Centipoise $\left[\frac{\text{gm.mass}}{\text{cm.-sec.}}\right]$ or $\left[\frac{\text{dyne-sec.}}{\text{cm.}^2}\right]$	100	1	47,880	6.895×10^{6}	1,488
$\left[\frac{\text{slugs}}{\text{ft.-sec.}}\right]$ or $\left[\frac{\text{lb.force-sec.}}{\text{ft.}^2}\right]$	2.088×10^{-3}	2.088×10^{-5}	1	144	0.03108
Reyns $\left[\frac{\text{slugs}}{\text{in.-sec.}}\right]$ or $\left[\frac{\text{lb.force-sec.}}{\text{in.}^2}\right]$	1.45×10^{-5}	1.45×10^{-7}	6.95×10^{-3}	1	4.48
$\left[\frac{\text{lb.mass}}{\text{ft.-sec.}}\right]$ or $\left[\frac{\text{pdl.-sec.}}{\text{ft.}^2}\right]$	0.0672	6.72×10^{-4}	32.17	0.223	1

ality factor μ can be determined from Equation (3) by rewriting

$$\mu = \frac{\tau}{U/h}$$

and introducing the dimensions of the respective quantities

$$[\mu] = \frac{[F/L^2]}{[L/T]\,[1/L]} = \left[\frac{F\ T}{L^2}\right] = \left[\frac{M}{L\ T}\right]$$

In the American System, the pound-force-foot-second-system, μ is expressed in pound-seconds per foot square or in slugs per foot second. In the c.g.s. system, it is dyne-seconds per square centimeter or grams per centimeter-second. In Table I conversion factors are given that cover a number of systems used in fluid flow calculations.

POISEUILLE-FLOW. Another interesting case of basic importance is the flow that results when a viscous fluid is pressed between two fixed parallel plates, separated by a small distance h. Here again the fluid in contact with the plates adheres and stays at rest relative to the plates and the velocity gradient du/dy gives rise to a shear stress τ that equals $\mu\ du/dy$. The forces acting because of these shear stresses must be in equilibrium with the forces resulting from the pressure difference. Considering a small fluid particle, as shown in Fig. 2, the difference of velocity between the lower and upper surfaces gives rise to a shearing stress. On the lower surface the adjacent layers of fluid are moving slower than the particle, therefore, the resulting force acts in a retarding sense. On the upper surface the opposite holds true and an accelerating force is the result. For steady state flow, where no inertia forces are acting, the equilibrium of the element requires that

$$[p - (p + dp)]\,dy - [\tau - (\tau + d\tau)]\,dx = 0$$

or $$dp\,dy = d\tau\,dx$$

$$\frac{dp}{dx} = \frac{d\tau}{dy} \tag{4}$$

With $\tau = \mu\frac{du}{dy}$ and $\frac{d\tau}{dy} = \mu\frac{d^2u}{dy^2}$

$$\frac{dp}{dx} = \mu\frac{d^2u}{dy^2} \tag{5}$$

By integrating with respect to y,

$$u = \frac{1}{\mu}\frac{dp}{dx}\frac{y^2}{2} + C_1y + C_2 \tag{5a}$$

For the boundary conditions

$$u = 0 \text{ for } y = \pm\frac{h}{2}$$

$$\text{or } u = -\frac{1}{2\mu}\left(\frac{h^4}{4} - y^2\right)\frac{dp}{dx} \tag{6}$$

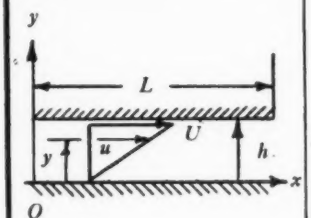
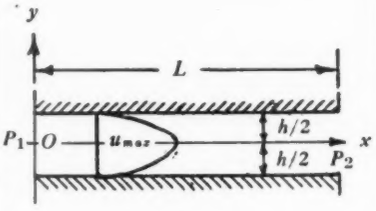
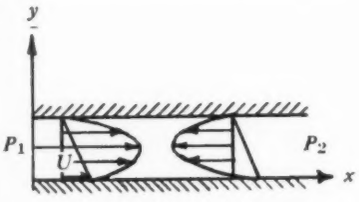
and u_{max} is obtained for y equal to zero, or the middle of the flow

$$u_{max} = \frac{h^2}{8\mu}\frac{dp}{dx} \tag{7}$$

Since the velocity u decreases with

Table II—Equations for Fluid Flow

Note: W = breadth of flow path

	Couette Flow "C"	Poiseuille Flow "P"	Combined Couette Poiseuille "C" + "P"
		 $P_1 > P_2$	 $P_1 > P_2$ I $U \rightarrow$ $P_1 < P_2$ II
Velocity u	$u = U\frac{y}{h}$	$u = -\frac{1}{2\mu}\frac{dp}{dx}\left[\frac{h^2}{4} - y^2\right]$	$u = \left(1 - \frac{y}{h}\right)U - \frac{1}{2\mu}y\,(h-y)\frac{dp}{dx}$
Total Flux Q	$Q_C = \frac{U}{2}hW$	$Q_P = -\frac{h^3}{12\mu}\frac{dp}{dx}W$	$Q_{CP} = \left(\frac{Uh}{2} - \frac{h^3}{12\mu}\frac{dp}{dx}\right)W$
Shearing Stress τ	$\tau = \mu\frac{U}{h}$	$\tau = \mu\frac{du}{dy} = \frac{dp}{dx}y$	$\tau = -\mu\frac{U}{h} - \frac{1}{2}(h - 2y)\frac{dp}{dx}$
Drag Force F	$F_C = \tau LW = \mu\frac{U}{h}LW$	When $y = h/2$ $F_P = \tau LW = \frac{h}{2}\frac{dp}{dx}LW$	$F_{CP} = \left(\mu\frac{U}{h} + \frac{h}{2}\frac{dp}{dx}\right)LW$
Energy Dissipation E	$E_C = FU = \frac{\mu}{h}U^2\,LW$	$E_P = (P_1 - P_2)\,Q_P = \frac{h^3}{12\mu}\frac{(\Delta P)^2}{L}W$	$E_{CP} = \frac{\mu}{h}U^2LW + \frac{h^3}{12\mu}\frac{(\Delta P)^2}{L}W$

the second power of y, the velocity distribution is parabolic and the mean velocity is equal to two thirds of u_{max}; accordingly, the total flux Q per unit breadth is

$$Q = -\frac{h^3}{12\mu}\frac{dp}{dx} \qquad (8)$$

COMBINED COUETTE AND POISEUILLE FLOW. When the lower plate is moving with a velocity U and the upper plate remains at rest, as shown in Fig. 3, the boundary conditions are

$u = U$ for $y = 0$
$u = 0$ for $y = h$

Introducing these conditions in Equation (5a) gives

$$u = \left(1 - \frac{y}{h}\right)U - \frac{1}{2\mu}y\,(h-y)\frac{dp}{dx} \qquad (9)$$

The total flux per unit breadth is

$$Q = \int_0^h u\,dy = \frac{Uh}{2} - \frac{h^3}{12\mu}\frac{dp}{dx} \qquad (10)$$

The shear stress at any point y is

$$\tau = \mu\frac{du}{dy} = -\frac{\mu U}{h} - \tfrac{1}{2}(h - 2y)\frac{dp}{dx} \qquad (11)$$

The drag per unit area on either boundary, where y equals 0 or h, is

$$\text{Drag} = \frac{\mu U}{h} \pm \frac{h}{2}\frac{dp}{dx} \qquad (12)$$

At this point a few words should be said about the pressure gradient dp/dx. Fixing, say, the direction of u or U as the positive direction, then dp/dx is positive when the pressure increases in this direction and negative in the opposite.

If the flow passage is of uniform cross-section and the fluid is incompressible, as is assumed in all present considerations, it follows that

$$\frac{1}{\mu}\frac{dp}{dx} = \text{constant}$$

If, furthermore, μ can be taken as constant, where L is the length of the passage

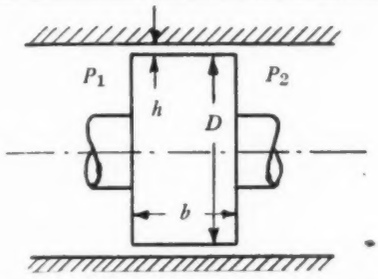
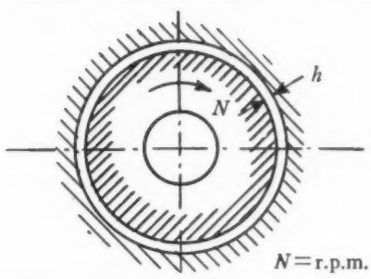
$$\frac{dp}{dx} = \text{constant} = \frac{P_2 - P_1}{L}$$

Unfortunately, μ is not a constant but varies with temperature and pressure. Since the variations with pressure are small for the great majority of practical applications, only the variations with temperature shall be considered in this discussion. Furthermore, it shall be assumed that only temperature changes of a moderate magnitude shall be encountered. Then, the derived formulas can be used safely by introducing an average value of the coefficient of dynamic viscosity

$$\mu_{av} = \frac{\mu_1 + \mu_2}{2} \qquad (13)$$

into the calculations, where the sub-

Table III—Coaxial Cylinders With Couette Drag and Poiseuille Flow

Couette Drag Tangentially		Poiseuille Flow Axially
		
Couette Drag	Energy Dissipated	$E_c = \frac{\mu}{h} U^2 LW = \frac{\mu}{h}\left(\frac{D\pi N}{60}\right)^2 D\pi b$
Poiseuille Flow	Slip Flow	$Q_P = \frac{h^3}{12\mu}\frac{\Delta P}{b} D\pi$
	Energy Dissipated	$E_P = \frac{h^3}{12\mu}\frac{(\Delta P)^2}{b} D\pi$
Heat Balance		$Jwc\,\Delta t Q_P = Jwct_1\,\delta\,Q_P = E_c + E_P$ $Jwct_1\,\delta\,\frac{h^3}{12\mu_m}\frac{\Delta P}{b} = \frac{\pi^2}{60^2}\frac{\mu_m}{h} D^2N^2b + \frac{h^3}{12\mu_m}\frac{(\Delta P)^2}{b}$
		$\frac{t_1\delta - \frac{\Delta P}{Jwc}}{\left[\left(\frac{1}{1+\delta}\right)^n + 1\right]^2} = \frac{\pi^2}{1{,}200}\frac{\mu_1{}^2}{Jcwh^4}\frac{D^2N^2b^2}{\Delta P}$

scripts 1 and 2 designate the values at the entrance and at the discharge respectively.

The formulas derived so far are given in Table II and expressions for the rate of energy dissipation E resulting from internal friction of the fluid have been added. For Couette flow the expression for E_c is equal to the mechanical power expenditure

$E_c = F\ U$

For Poiseuille flow, E_P is equal to the rate at which hydraulic energy must be supplied to transport the fluid through the gap

$E_P = Q\ P$

For combined Couette Poiseuille flow, where a mechanical input

$E_m = F\ U$

and a hydraulic input

$E_{hyd} = Q\ P$

are encountered, the energy dissipated into heat is

$E_{heat} = E_m + E_{hyd}$

and

$E_{cP} = E_c + E_P$

By dividing E by the mechanical heat equivalent J, 778 ft. lb. per B.t.u., the dissipated mechanical energy can be equated to the heat produced in the fluid:

$$H = E/778 \text{ B.t.u. per sec.} \qquad (14)$$

where Q = rate of flow, cu. ft. per sec.
w = specific weight of the fluid, lb. per cu. ft.
c = specific heat of the fluid, B.t.u. per lb. per deg. F.
Δt = rise in temperature between entrance and discharge, deg. F.

then

$Q\,w\,c\,\Delta t = H = E/778$

or

$$\Delta t = \frac{E}{778\,Q\,w\,c} \qquad (15)$$

For the change of viscosity with temperature, only lubricating oils shall be considered, since they are the main group of liquids used in the viscous range of flow, to which all these considerations pertain. For the purpose of analysis it is more convenient to use the empirical straight line relationship, found by Herschel, between the logarithm of the viscosity in centipoises and the logarithm of the temperature in degrees Fahrenheit, instead of the ASTM Standard Viscosity-Temperature Charts for liquid petroleum products. The Herschel relationship gives sufficient accuracy between 100 and 300 deg. F. when the chart is drawn from viscosity measurements at 100 and 210 deg. F. From such a log-log plot of viscosity versus Fahrenheit temperature, Fig. 4, the slope n can be found from the relationship

$$n = \tan\alpha = \frac{\log\mu_1 - \log\mu_2}{\log t_2 - \log t_1}$$

or

$$\mu_2 = \mu_1\left(\frac{t_1}{t_1 + \Delta t}\right)^n$$

$$\mu_m = \frac{\mu_1 + \mu_2}{2}$$

$$= \frac{\mu_1}{2}\left[1 + \left(\frac{t_1}{t_1 + \Delta t}\right)^n\right]$$

The temperature rise Δt expressed

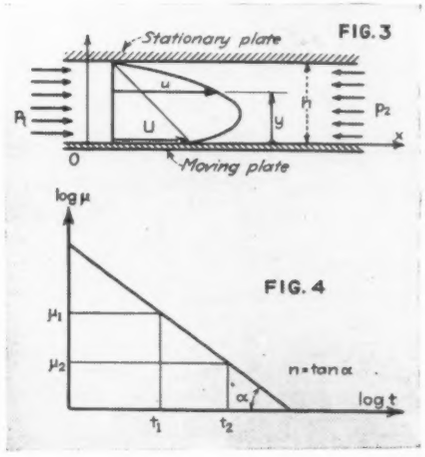


Fig. 3—Velocity distribution in combined Couette and Poiseuille flow between parallel plates. Fig. 4—Log-log plot of relation between viscosity of an oil and Fahrenheit temperature.

in terms of the initial temperature, where δ is the ratio of Δt to t_1 is

$$\Delta t = \delta\, t_1 \qquad (16)$$

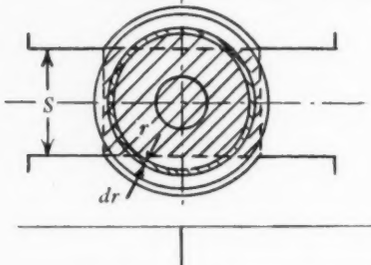
then

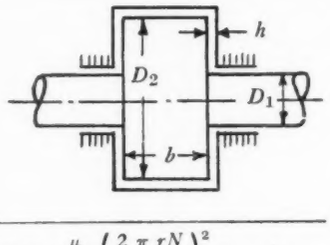
$$\mu_m = \frac{\mu_1}{2}\left[1 + \left(\frac{1}{1+\delta}\right)^n\right] \qquad (17)$$

With these elementary concepts

Table IV—Disk Friction and Poiseuille Flow

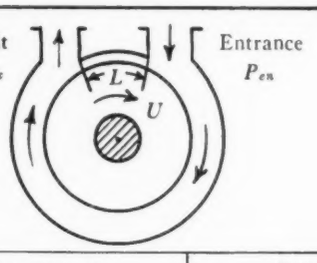
Note: Only one side of disk is considered

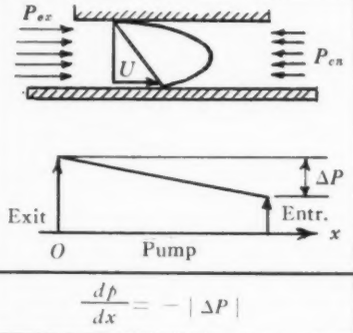
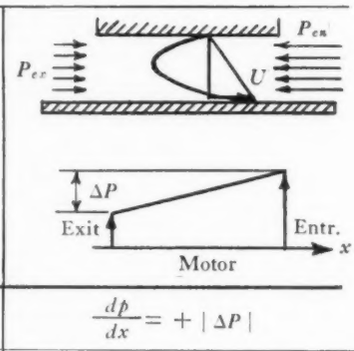




Couette	Energy dissipated	$dE_C = UdF = \frac{\mu}{h}\left(\frac{2\pi rN}{60}\right)^2 2\pi r dr$
		$E_C = \frac{1.077}{10^3}\frac{\mu}{h} N^2 (D_2^4 - D_1^4)$
Poiseuille	Slip flow	$Q_P = \frac{h^3}{12\mu}\frac{\Delta P}{D_2} S$
	Energy dissipated	$E_P = \frac{h^3}{12\mu}\frac{(\Delta P)^2}{D_2} S$
Heat Balance		$Jc_w \Delta t Q_P = E_C + E_P$
		$Jc_w \Delta t \frac{h^3}{12\mu_m}\frac{\Delta P}{D_2} S = \frac{1.077}{10^3}\frac{\mu_m}{h} N^2 (D_2^4 - D_1^4) + \frac{h^3}{12\mu_m}\frac{(\Delta P)^2}{D_2} S$
		$\frac{t_1\delta - \frac{\Delta P}{Jc_w}}{\left[\left(\frac{1}{1+\delta}\right)^n + 1\right]^2} = \frac{3.23\,\mu_1^2 N^2 D_2 (D_2^4 - D_1^4)}{\Delta P S J c_w h^4}$

Table V—Flow Between Rotor and Division Plate



		
Pressure Gradient	$\frac{dp}{dx} = -\lvert\Delta P\rvert$	$\frac{dp}{dx} = +\lvert\Delta P\rvert$
Slip flow	Pump $Q = \left[\left(\frac{D\pi N}{60}\right)\frac{h}{2} + \frac{h^3}{12\mu}\frac{\Delta P}{L}\right] W$	Motor $Q = \left[\left(\frac{D\pi N}{60}\right)\frac{h}{2} - \frac{h^3}{12\mu}\frac{\Delta P}{L}\right] W$
Energy Dissipated	$E_C = \left[\frac{\mu}{h}\left(\frac{D\pi N}{60}\right)^2 L + \frac{h^3}{12\mu}\frac{(\Delta P)^2}{L}\right] W$	
Heat Balance	$Jc_w \Delta t Q = E_C$ $Jc_w \Delta t \left[\frac{D\pi N}{60}\frac{h}{2} + \frac{h^3}{12\mu_m}\frac{\Delta P}{L}\right] = \frac{\mu_m}{h}\left(\frac{D\pi N}{60}\right)^2 L + \frac{h^3}{12\mu_m}\frac{(\Delta P)^2}{L}$	$Jc_w \Delta t Q = E_C$ $Jc_w \Delta t \left[\frac{D\pi N}{60}\frac{h}{2} - \frac{h^3}{12\mu_m}\frac{\Delta P}{L}\right] = \frac{\mu_m}{h}\left(\frac{D\pi N}{60}\right)^2 L + \frac{h^3}{12\mu_m}\frac{(\Delta P)^2}{L}$

clarified, almost everything is done that is necessary to solve a great number of practical applications in the range of viscous flow. The remaining problem is to make the right combinations of these concepts.

Design Formulas

In Table III are given formulas for the energy dissipated by Couette drag (tangentially) and Poiseuille flow (axially) for coaxial cylinders with a pressure difference in the axial direction. Formulas are also given for the slip flow and for the temperature rise when it is assumed that heat is carried off by the flow only and none by heat transfer through the inclosing walls. The equation for the heat balance presents the relation between the known quantities, such as geometrical dimensions, pressure, initial viscosity and temperature, and the unknown quantity, the relative temperature rise δ. The exponent n is found from the Herschel chart of the particular oil being used in the application.

In Table IV are given formulas for the energy dissipated by disk friction and Poiseuille flow between the end surfaces of a rotating cylindrical body and the corresponding inner surfaces of the housing. The energy loss resulting from drag can be calculated by considering a differential annular strip dA equal to $2\pi rdr$ and integrating between the limits $D_1/2$ and $D_2/2$. As a simplification it was assumed that the leakage flow takes place through the shaded area S times D_2. This assumption is rather crude; but the results obtained by this method will be sufficiently accurate for many practical designs.

In Table V are given formulas for flow between a rotor and division plate. This case is a direct application of the "Combined Couette-Poisuille Flow" shown in Table II. There is a variety of practical cases that are identical in principle, as for instance the flow across the top of a gear tooth in a gear pump. For the leakage flow it is important to note whether the pressure gradient — dp/dx and the velocity vector U are acting in the same or in opposite directions. When they act in the same direction the flow resulting from Couette drag and the Poiseuille flow add, in the opposite case they subtract.

NEW BOOKS

Applied Engineering Mechanics

ALFRED JENSON. 6 x 9 *in.*, 316 *pages, red clothboard covers. Published by McGraw-Hill Book Co., 330 W. 42nd St., New York* 18, *N. Y. Price* $3.

An elementary text on engineering mechanics that requires for its understanding only a knowledge of high-school mathematics. The author has minimized the more abstract mathematical relations and has strongly emphasized the physical concepts that are essential in grasping the fundamental principles of mechanics.

The content of the book is divided into two main parts: Statics and Dynamics. Analytical and graphical solutions are both given to encourage students to use one as a check upon the other. Nearly 500 illustrations and more than 900 exercise problems are included.

Electronics for Industry

WALDEMAR I. BENDZ, *Electrical Engineer, Westinghouse Electric Corp.*, 501 *pages,* 6 x 8½ *in., clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York* 16, *N. Y. Price* $5.

Practical, non-mathematical discussion of industrial applications of electronic control circuits, power rectification, and induction and high frequency dielectric heating.

Designed principally for the engineer who is already familiar with fundamentals of electrical devices, the book outlines the functions of all kinds of electronic tubes and explains the basic circuits commonly used for industrial applications. The seventeen chapters include discussions of thyratrons, multigrid tubes, amplification, oscillation, control circuits, regulators, and typical industrial applications.

Milling With Carbides

Technical Committee on Carbide Milling Cutters: 44 *pages,* 8½ x 11 *in., paper covers. Published by Metal Cutting Tool Institute,* 6400 *Chrysler Building, New York* 17, *New York. Price* $1.

A comprehensive, authentic and concise report on the various phases of carbide milling, compiled by a technical committee of the Metal Cutting Tool Institute.

The report deals with the economic and practical factors relating to carbide milling applications, characterstics of various grades and brands of carbides, illustrations and nomenclature of the different elements of common types of carbide milling cutters, the importance of proper and adequate machine tools and fixtures, carbide milling cutter design, operating techniques for carbide milling, and the sharpening and care of carbide millng cutters.

Sufficient information is contained in the report to enable the reader to intelligently discuss and evaluate the problems peculiar to the design, manufacture, application, and use of carbide milling cutters.

Preparation and Use Of Visual Aids

KENNETH B. HASS *and* HARRY Q. PACKER. 224 *pages,* 6 x 9 *in., clothboard covers. Published by Prentice-Hall, Inc.,* 70 *Fifth Ave., New York* 11, *N. Y. Price* $4.

The book gives details on how to use, how to prepare and where to find visual aids, including motion pictures, stripfilm, sound slidefilm, training slides, maps, charts, graphs, flash cards, posters and manuals, pictures and photographs, objects and models, field trips and television.

Relative merits of the different types of visual aids are discussed along with the practical application of visual aid in job training and educational programs, sales demonstrations and displays and advertising. Printed training aids and sources of visual aids are covered in appendixes.

Analysis and Design Of Translator Chains

H. ZIEBOLZ. *Volume I, Text,* 277 *pages. Volume II, Diagrams,* 133 *pages,* 5½ x 8½ *in., paper covers. Published by Askania Regulator Company, 1603 S. Michigan Ave., Chicago, Ill. Price* $5.

A systematic approach to the classification of mechanical, hydraulic, electrical, electronic and other technical devices and to the reduction of them to basic elements for use in solving problems of instrumentation. The symbols, which are adaptable to typing, are set up to cover systematically the whole technological field.

Believing that "one of the greatest handicaps in arriving at an optimum solution is the early discovery of one possible soluton" the author presents a technological "map" on which each "translator" device is assigned a definite position in relation to each one of the variables that can form an input or output of the translator chain. Thus all possible solutions are indicated and can be analyzed and compared. The mathematical operations with translator chains, namely summarization, multiplication, differentiaton and integration are treated in connection with types of devices to perform these operations.

Descriptive Geometry

E. F. WATTS *and* J. T. RULE. 301 *pages,* 6 x 9 *in., red clothboard covers. Published by Prentice-Hall, Inc.,* 70 *Fifth Ave., New York, N. Y. Price* $4.

This volume covers the basic material of elementary graphical theory applicable to engineering problems. It is aimed at developing the ability of the engineer to solve such problems by the simplest graphical methods. The greater part of the volume deals with the descriptive geometry and theories made use of in graphical solutions.

Since the graphical solution of an engineering problem does not always fall in the field of descriptive geometry, the authors have included chapters covering precision in drawing and the properties of plane figures.

The chapter on stereoscopic drawing is supplemented with a stereoscopic plate and viewer to illustrate the type of result achieved with this type of drawing.

Panel Heating And Cooling Analysis

B. F. RABER *and* F. W. HUTCHINSON. 208 *pages,* 5½ x 8½ *in., red clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York* 16, *N. Y. Price* $3.50.

A theoretical and practical discussion of the general principles, design features, types of equipmen, and special uses of radiant surfaces.

The introductory chapters present non-technical descriptive material, on the background, development, advantages, disadvantages, and types of installations of panel heating and cooling systems.

The greater portion of the book is intended as a reference for design engineers and research workers, and a textbook for engineering students. Thi section is a detailed and rigorous treatment of the theory of radiant exchange and a mathematical analysis of radiant panel heating and cooling systems. Basic experimental and analytical data are included covering shape factors of surfaces with respect to one another and of occupants with respect to surfaces.

A number of practical numerical examples are given that show how the concept of equivalent conductance can be applied in a design procedure, yet retain a high degree of accuracy.

TECHNICAL NEWS HIGHLIGHTS

Coal-Burning Gas Turbine Power Plant

A NEW PRIME MOVER, containing some unique features and promising to be as economical as its competitors, has been developed by the Locomotive Development Committee of Bituminous Coal Research, Inc. Answering the threat of diesel engines to the coal market, six major coal-carrying railroads and three of the largest coal producers organized the Locomotive Development Committee to investigate the possibilities of a coal-burning gas turbine as a locomotive prime mover. This program has been under way since May 1, 1945, and results have recently been reported.

Efficiency of Steam Engine

The steam locomotive, although dominating the railroad field, is limited in thermal efficiency as long as it must use the Rankine cycle with atmospheric exhaust. The deficiency of the steam cycle arises from its difficulty in disposing of the heat which it cannot use. No practical condensing steam locomotives have yet been developed in the United States, and there seems to be no immediate prospect of such a development. Another major obstacle to efficiency is the large amount of coal per hour which must be burned in the restricted fire box of a locomotive.

In order for a steam power plant to begin to compete with the Diesel, the exhaust pressure on the steam engine must be reduced to the lowest possible value by the use of a condenser, which has not been found practical. If possible, however, the efficiency of the ordinary locomotive could be raised to 15 percent. The coal-burning steam locomotive rarely attains a thermal efficiency above 7 percent. In addition, the reciprocating mechanism causes a dynamic unbalance which results in severe rail pounding.

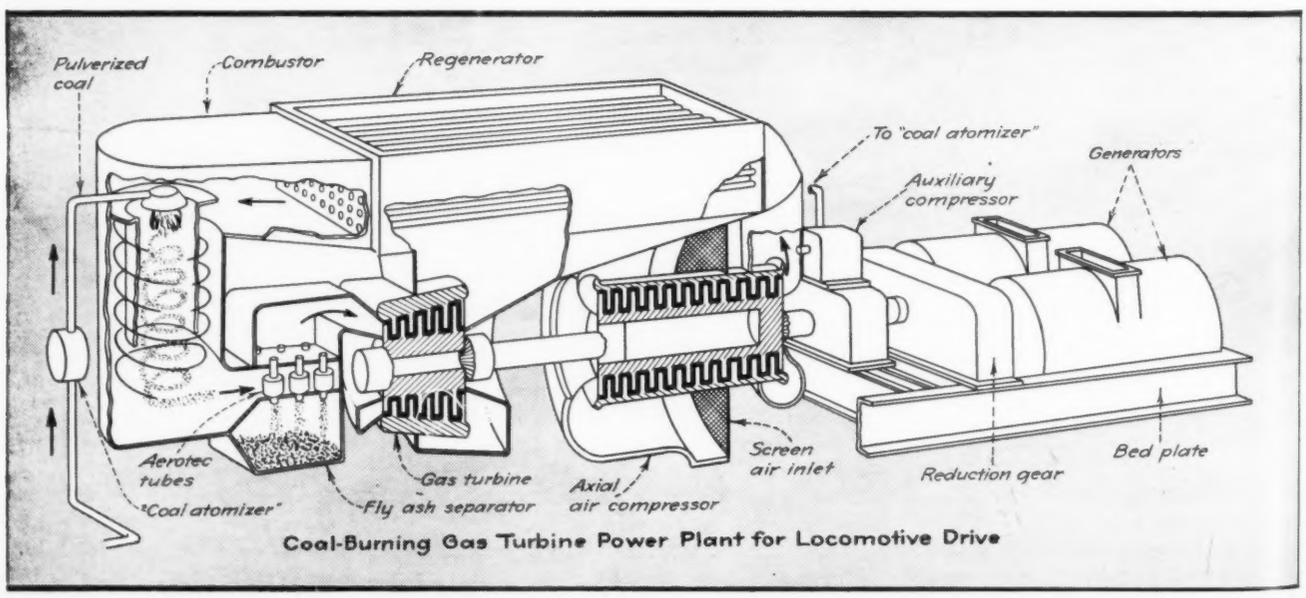
The operating cost of any power plant, is a function of the fuel cost as well as efficiency. Of greater importance than the price per ton or per gallon is the worth of each fuel in terms of cents per million B. Th.U. of heating value. Coal costs the average American railroad about 15 cents per million B.t.u. Diesel oil, a distillate fuel of high quality, costs approximately 45 cents per million B.t.u., while the heavy oil known as Bunker C varies in price from about 30 cents per million B.t.u. on the east coast to 20 cents per million B.t.u. in the west, where oil is plentiful. The fuel cost for a horsepower hour is calculated from the following equation:

$$\text{cents per hp. hr} = \frac{2545}{\text{thermal efficiency}} \times \text{cents per B.t.u.}$$

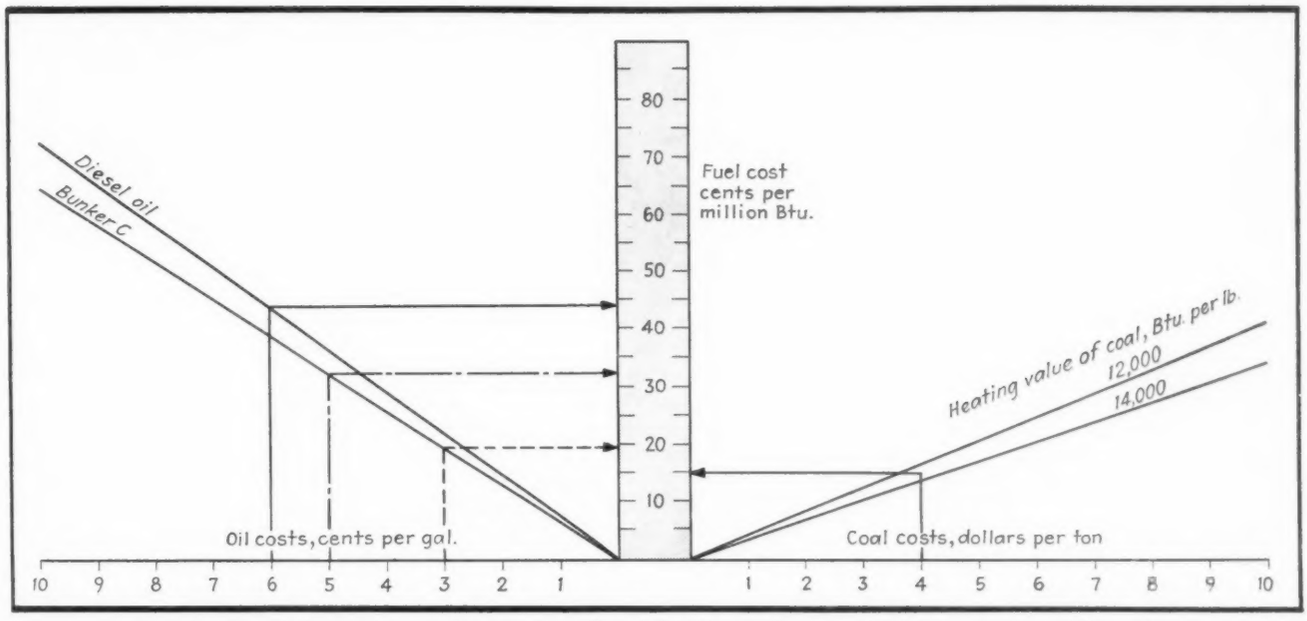
The operating cost of the modern steam locomotive is higher than the diesel locomotive. However, the low cost of coal as a fuel interested the Locomotive Development Committee, and the possibilities of the gas turbine seemed attractive. The result is the pulverized coal gas turbine locomotive, which, the Committee claims, gives even lower operating cost than the diesel locomotive.

Coal-Burning Gas Turbine

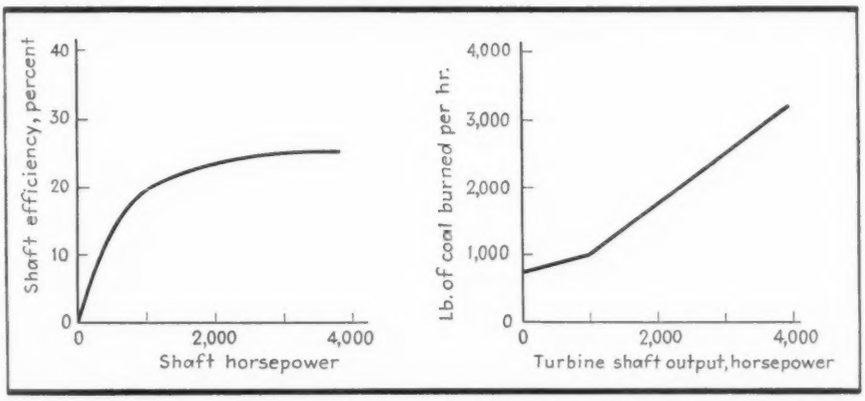
The major problems in developing the coal-burning gas turbine were to prepare the coal on the locomotive, to



Coal-Burning Gas Turbine Power Plant for Locomotive Drive



More important than price per ton or per gallon is heating value of a fuel in cents per million Btu.



Typical performance curves for gas turbine for coal-burning locomotive.

pulverize it so finely that it could be burned completely within the rigid space limitations imposed by locomotive clearances, and to remove enough of the flyash from the combustion products to insure a reasonable life for the turbine blades.

In the final design of the turbine, the coal is carried in a bunker which is mounted on the locomotive itself. This will be regular locomotive coal, and will be prepared for combustion on the locomotive itself. The coal will be transported from the bunker by means of a screw feeder similar to the conventional locomotive stoker. The coal will then be crushed and dried to a point where it will feed through the later stages of the process. The gas turbine exhaust supplies all of the hot air which can possibly be needed for drying. The coal coming out of the crusher will be about as coarse as percolator grind coffee, and at this stage it will be put into a chamber where the pressure is about 140 lb. per sq. in. Several different types of coal pump which will pressure the coal have been developed.

The coal is fed from the pressurized storage tank as it is needed. It's picked up by a stream of rapidly flowing compressed air, which carries it in a fraction of a second to the "coal atomizer." The atomizer is a device in which the particles of coal are caused to pass through a nozzle. The pressure outside of each coal particle will suddenly drop from about 140 lb. per sq. in to about 60, and the air trapped within the pores of the coal cannot escape through these pores. The air "explodes" the coal into tiny fragments, and these particles are further pulverized by the high velocity of the air-coal mixture issuing from the nozzle in a simple attrition chamber. The fineness of pulverization accomplished by the coal atomizer is advantageous, because of the ease with which this atomized coal burns.

When pulverized coal is burned, each individual particle leaves behind it a smaller fragment of ash, and it has been a difficult problem to remove this substance, which is known as "fly ash." Fly ash will have some abrasive effect, unless the larger particles are removed. By putting the dust-laden hot air through a battery of small cyclone separators such as those produced by the Aerotec Company, as much as 95 percent of the fly ash can be removed. The disposal of the fly ash which is collected in the separator will be a relatively minor problem, because there will be only about 5 lb. of ash per mile, instead of at least ten times this amount which is now discharged from conventional steam locomotives.

The Locomotive Development Committee has on order two gas turbines and two locomotives. The Allis-Chalmers Company of Milwaukee is building a gas turbine which will have a shaft power of about 4,200 hp. The Elliott turbine will be rated at 3,750 hp. Each of these turbines will drive dc. electric generators, and electric motors, in turn, will drive the wheels of the locomotive, in just the same way that Diesel locomotives are operated. Typical operating characteristics for one of the new turbines are shown in the accompanying curves.

The time schedule of the Locomotive Development Committee calls for the operation of the two full-scale gas turbines in the builders' plants during the first months of 1948. It is expected that the coal-handling and combustion equipment will be built and tested by that time, so that the units should be ready for installation in experi-

mental locomotives during the latter part of the spring of 1948. Extensive trial runs will be made, to determine the suitability of the entire plants for American railway operation.

National Inventors Council Lists Problems to be Solved

THE NATIONAL INVENTORS COUNCIL has released a list of 25 technical problems posed by the Army, Navy, and Coast Guard for solution by American inventors. Covering such diverse fields as lightweight Diesel engines, miniature radio transmitters, fog detectors, structural metals, and solidifaction of soils, each problem is a current technical need of one of the services.

The problems listed are accompanied by statements of the military application of the device or technique being sought and the present status of similar technical developments.

In announcing the list of problems, John C. Green, chief engineer of the National Inventors Council and director of the Office of Technical Services, stated that NIC wants to learn of any progress made by private laboratories in solving these problems that is not now known to the armed forces. The NIC also wishes to inform American inventors that the Army, Navy, and Coast Guard are as much interested in new and better equipment today as they were during the war years. The services, according to Mr. Green, are especially interested in encouraging former servicemen who have had personal experience with present-day equipment to propose innovations and improvements.

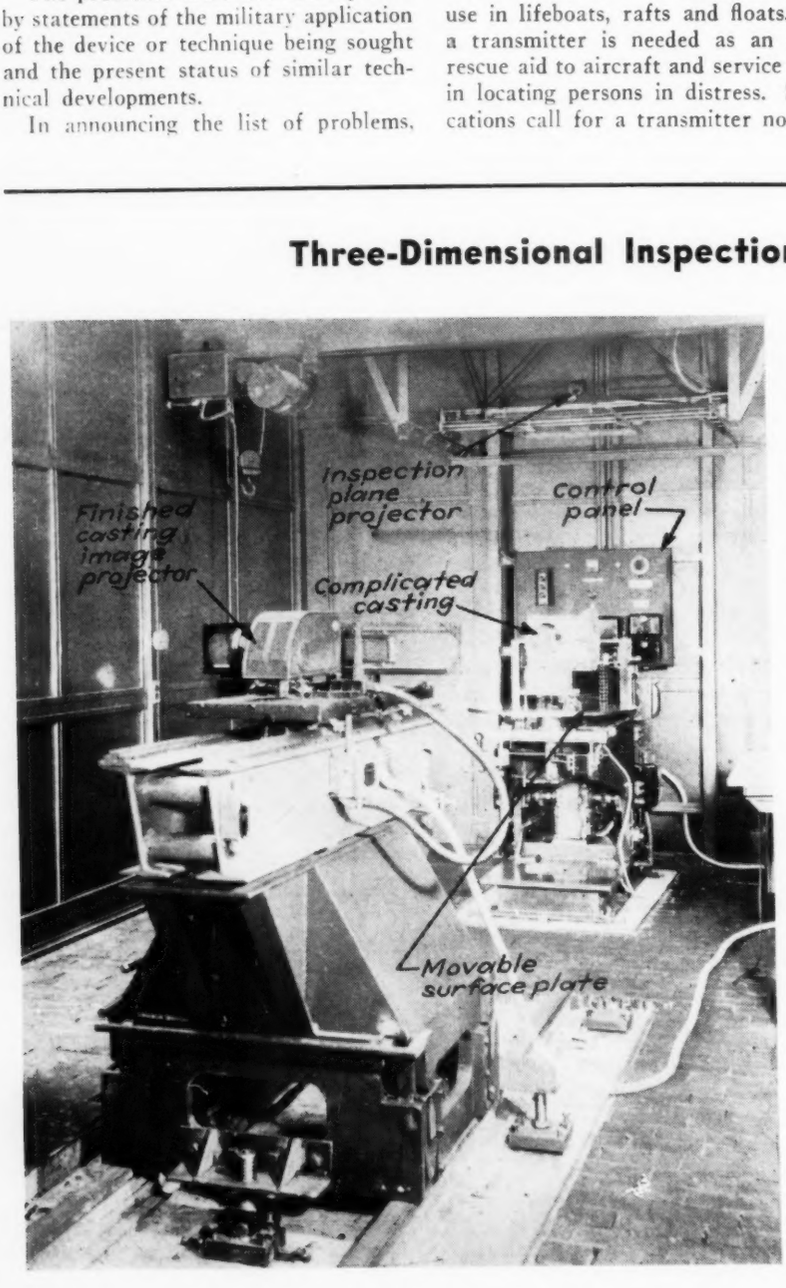
Typical of the problems is the need for a miniature radio transmitter for use in lifeboats, rafts and floats. Such a transmitter is needed as an air-sea rescue aid to aircraft and service vessels in locating persons in distress. Specifications call for a transmitter not more than 15 inches long and 2½ inches in diameter, weighing not more than a pound, powered either by battery or hand generator.

The Coast Guard needs a device to detect the presence of fog, rain squalls or snow, which reduce visibility around a light vessel to less than one mile, and which will indicate the presence of a fog bank three to four miles away. The device is needed to operate fog signals on unattended light vessels.

All proposals received will be studied by the National Inventors Council and its operating staff. Those recommended will be sent to the proper branch of the Army, Navy, or Coast Guard for further examination. A full statement of the technical problems may be obtained by writing to the Council.

Mr. Green explained that any inventor with a suggestion may disclose it to the Council without jeopardizing his patent rights. His disclosure will be dated and kept in a confidential file.

Three-Dimensional Inspection of Castings



INSPECTION AND LAYOUT of castings by a three-dimensional method of projecting accurate layout drawing on rough castings has been developed by General Electric engineers and has seen several years of successful application to intricate ferrous and nonferrous castings. This method is claimed to effect considerable savings in time and material. An unskilled operator with a few days training can use this method. This method has been used for rapid inspection of finished parts. Projection may also be employed during an actual machining process, whether the part to be machined is stationary or revolving. The equipment assures layout within 0.015 inch.

The apparatus consists of a layout image projector containing a photographic glass slide of the finished casting layout. The layout is projected by a lens directly upon the surface of the casting. To establish the plane of true projection and correct dimensions, a second projector—the inspection plane projector or light wand—over the inspection position is used. The light wand emits a sheet of light which falls vertically upon the casting. Both projectors operate in unison through a selsyn system. Thus, the light wand always designates the proper plane, focus and size for the main projector's image.

The inspection pedestal assists in positioning the rough casting by means of an electric drive. An adjustable surface plate allows for the final location of the casting coincidental to the sheet of light from the inspection plane projector.

When machining a piece which is symmetrical about the axis of rotation, the finished outline may be projected to serve as a template.

WASHINGTON NOTES

Justice Department Patent Report Issued

The increasing imporatnce of the research and patent policies of the Federal Government is directing attention to a four-year study of government patent practices and policies made by the Department of Justice. (See July "Washington Notes").

The three-volume, 1000-page report, recently released by the White House, is a mine of information on the development of the patent practices and policies of 14 government agencies and 10 foreign countries. It also contains short summaries of the patent practices of private and educational research laboratories, and those of private industry.

The Department of Justice recommends the creation of a Government Patents Administration with authority to administrate, interpret and enforce a uniform government patent policy as established by the President. The Patent Administration would settle any inter-agency controversies arising from that policy. The Patent Administrator would be appointed by the President, and would be assisted by an advisory board representing a dozen government departments and representatives of industry, labor, education and the public.

The report states that the policy recommended does not conflict with any existing laws or the present patent system. The recommendations could be put into effect at any time by executive order, since they have to do only with the executive branch of the government.

Important features of the report's findings and recommendations are:

1. All rights to inventions developed under Government-financed contract should be assigned to the government.

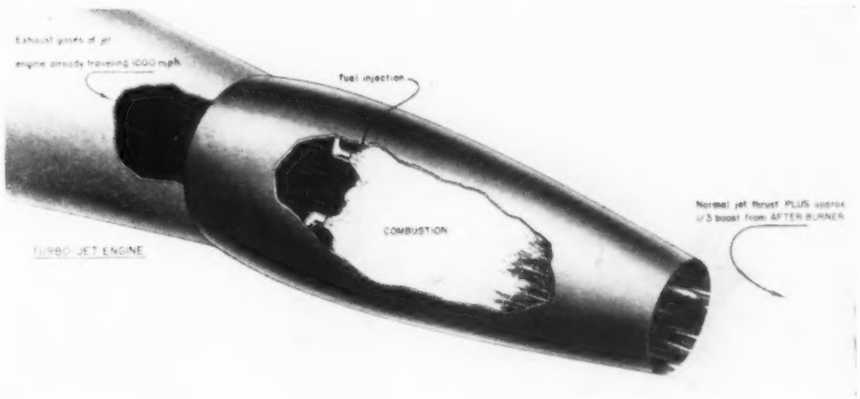
2. Exceptions should be permitted in emergency situations where the contractor has already made a "substantial independent contribution." But the government in all cases would get a free license.

3. Government-owned patents should be available for general public use. Where exploitation of a government patent is discouraged by amount of investment necessary, government should finance development work, in whole or in part, to demonstrate value of the invention. This is deemed preferable to grant of exclusive licenses.

4. Financing of research by general taxation is preferable to licensing government inventions on a royalty basis.

In general, this final report is less drastic in its effect than those recommendations reported to be contained in earlier drafts. However, its recommendations are contrary to the long-established policy of the armed services. The Army and Navy have always allowed their contractors to take out patents, always with the provision that the government get a royalty-free license.

The just-issued patent report and the studies of the President's Scientific Research Board on the goals of government and private research (to be released later this summer) form the basis for the government's highly significant long-range plans for the development and guidance of U. S. scientific research.



PROPULSIVE THRUST OF HOT GASES blasting from the tailpipe nozzles of jet engines are claimed to be boosted as much as one-third by the Ryan "after burner," shown here in an artist's conception. Designed for actual flight, the Ryan unit is expected to be the first American after burner to be used in the air.

This thrust-augmentation is accomplished by spraying additional fuel into the tailpipe where its burning adds greater mass and velocity to the gases already in the jet exhaust stream. The problem of burning fuel and maintaining combustion in the after burner's short length is a critical one.

Developed by the Ryan Aeronautical Company for the Navy's Bureau of Aeronautics, the after burner will enable pilots to use the additional propulsive thrust to push their planes through the compressibility barrier as flight approaches the speed of sound. After burner will also be used to give added power for take-off.

Atomic Energy Commission Girded for Action

The Atomic Energy Commission is gradually whipping together a subtle organizational pattern unique among federal agencies. There are many holes in it, partly because of the continuing difficulty in filling top and second level jobs.

The Washington offices of the AEC will work at the planning and policy-making level. Nearly all operating jobs, administration of contracts, dealings with industry will be handled through five or more regional managers in New York, Chicago, Oak Ridge, Hanford, and Los Alamos. The Commission members themselves, in Washington, are taking on no administrative responsibilities, are devoting themselves to policy-making and working with the Congressional Joint Committee on Atomic Energy.

All administration centers in General Manager Carroll Wilson. He has two assistants, Richard O. Niehoff and John A. Derry. Assistant General Manager, responsible for relations with other government agencies, is G. Lyle Bellesley, who came with the commission several months ago.

Reporting to Wilson are a group of staff units, corresponding in function to the general staff divisions of the army. Four of them, set up by statute, are called divisions: The production division, headed by Walter J. Williams; the research division under James Fisk; the military division under General James McCormack; and an engineering division.

The one "geo-functional" office now operating is in New York, headed by Wilbur E. Kelley. This office is handling the construction of the Brookhaven laboratory on Long Island. It may be made responsible for the Knolls Atomic Power laboratory at Schenectady. For the whole country, it han-

A 650 POUND PLASTICS PART has been shipped from General Electric's plastics division in Pittsfield, Mass., to be used as a component part of the University of California's newest atom smasher. The largest of the synchroton parts is eight feet in diameter. Together with nine additional plastics parts, they will form the vacuum chamber of the atom smasher. The physical properties of the plastics offer strength, stability and electrical insulation.

The synchrotron plastics parts consist of seven rings and three vacuum manifolds made of a low-pressure laminated construction to form the vacuum chamber in which electrons are accelerated. The rings are designed to bear the compressive load of the magnet and are made of layers of glass fibers bonded with a polyester resin. The new synchrotron is designed to produce a beam of 300,000,000 volt X-rays and combines certain features of the cyclotron with those of the betatron, weighing less than either type.

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dles purchases of materials, including uranium and thorium, and it administers AEC's licensing system on uranium and thorium ores.

While AEC is settling down, the Congressional Joint Committee is setting up a staff of its own to enable it to keep in constant detailed contact with AEC operations. It will have some 20 staff members, headed by Fred B. Rhodes, Jr., a former Manhattan District security officer. There's no intention of putting congressional representatives in each AEC shop, but the staff members will be constantly "visiting around."

MONSANTO QUITS—Meanwhile, the Monsanto Chemical Co. decided to quit its job as operator of the Atomic Energy Commission's Clinton laboratory at Oak Ridge. AEC is looking for a new operator—perhaps another industrial firm, more likely a university or group of universities as at the Argonne and Brookhaven regional laboratories. The shift at Clinton underlines a major change in the emphasis of the atom project—a change which has been gathering force for several months now. AEC is gearing itself for an atomic armament race.

Administration policy is now based on the assumption that negotiations on the international control of atomic energy are getting nowhere. State Dept. and White House advisors are convinced that the Russians are stalling —perhaps until the time in the early 1950's when they have bombs of their own and can bargain on more nearly even terms. AEC chairman Lilienthal openly gave the foreign negotiators notice that he was setting out to make this country atomicly strong.

What this means to the atomic program is an increased emphasis on research and engineering that can show results—in increased and improved production of fissionable material, or bomb stuff. It means that preoccupation with industrial and beneficial applications of nuclear energy are moving into the background, and that secrecy on atomic matters is being tightened rather than relaxed.

Power generation work has not by any means been abandoned. For at the present stage of development, there is practically no distinction between work on industrial power and work on atomic propulsion for ships or aircraft. And even where a distinction exists, much preliminary work can be done in utility-type power generation without serious conflict with immediate military projects.

However, construction of atomic central-station power plants now looks considerably farther away than it did a few months ago. Six to ten years away, Lilienthal now says, instead of the four or five years atomic engineers were predicting earlier.

The change in timing can involve some substantive changes. For instance, the problem of whether to proceed immediately with construction of new plutonium production facilities or to go in for more elaborate engineering that would permit a multi-purpose job, utilizing the byproduct power might well get a different answer in the light of the new policy. The conflict between the military and civilian sides of the program is not a matter of money or of fissionable materials. Both are plentiful. It's a matter of skilled manpower—particularly of engineering rather than scientific manpower.

It is in industry that engineers are found. Thus, the current trend of AEC policy is to throw projects leading toward military objectives into the hands of industry, where early applications can be engineered on the basis of existing knowledge. Projects involving beneficial applications, are being routed toward the universities which can work out underlying theory and make studies preliminary to actual design.

Some industrialists are unhappy about the present trend. Although they admit the need for a recasting of the program, they doubt the wisdom of a mechanical separation between engineers and scientists. They argue that in many cases both basic research and engineering go forward faster if they enjoy the stimulation of indusion in

the same organization. Thus they feel that some research physicists will be less content and less productive on a university staff than they would be doing the same work in an industrial laboratory.

Against this background, Monsanto's decision to drop its management of Clinton is more comprehensible than at first appears from the explanation provided in a joint Monsanto-AEC statement. According to the statement, Monsanto wanted to transfer the Clinton projects to Dayton, Ohio, where the company has its own central research laboratory and where it is now building a new AEC facility—the Miami engineer works. Work at Clinton includes production of radio active isotopes, chemical research, health-physics research, work on an atomic power-generating unit, and a training school.

When AEC was unwilling to approve the transfer, Monsanto asked the commission to find another operator.

The current shift in AEC planning goes far to explain the bafflement of electric power people—both public and private—who have found themselves unable to get any very realistic help from the commission in planning their operations to take account of the coming impact of nuclear fission. Private utility men have been irritated and puzzled by the polite but innocuous level at which meetings between AEC and the utility advisory committee have been conducted.

Paralleling AEC's trend toward projects that will pay off militarily in a few years is a somewhat similar attitude in the military services. Both the Navy and the Army Air Forces show signs of losing their enthusiasm of last year for long-range programs of basic research farmed out to the universities. The Office of Naval Research, which handles such work for the sea service, has lately been favoring programs with definite military application.

Office of Technical Services Being Disbanded

The fate of the Office of Technical Services of the Department of Commerce was settled by House and Senate Appropriations Committee members. Having at first been refused any appropriation whatsoever for 1948 by the House, OTS and Commerce Department officials were later assured that funds would be given them, to provide for an orderly liquidation of their operations in Germany. This means that the documents in Germany that have been micro-filmed or ready for microfilming will continue to be processed and shipped here.

The outlook is that OTS will be able to carry on its cataloging, evaluating and publishing of technical reports, although on a much smaller scale than was provided by the 3.7 million dollars available in 1947. Barring unforeseen opposition to a minimum program recommended by House-Senate conferees, it appeared last month that 1 million dollars might be made available to carry on classifying, and abstracting—on a more limited scale.

On the strength of these assurances, OTS personnel in Germany are given until October 31 to wind up their work. All original investigations ceased on June 30.

Meanwhile, nearly 200 technical societies and industrial firms have volunteered to cooperate with OTS in evaluating, and screening on "raw information" from Germany. OTS last month was preparing to distribute documents to these groups, but awaiting final word from Congress on appropriations before putting this program into effect.

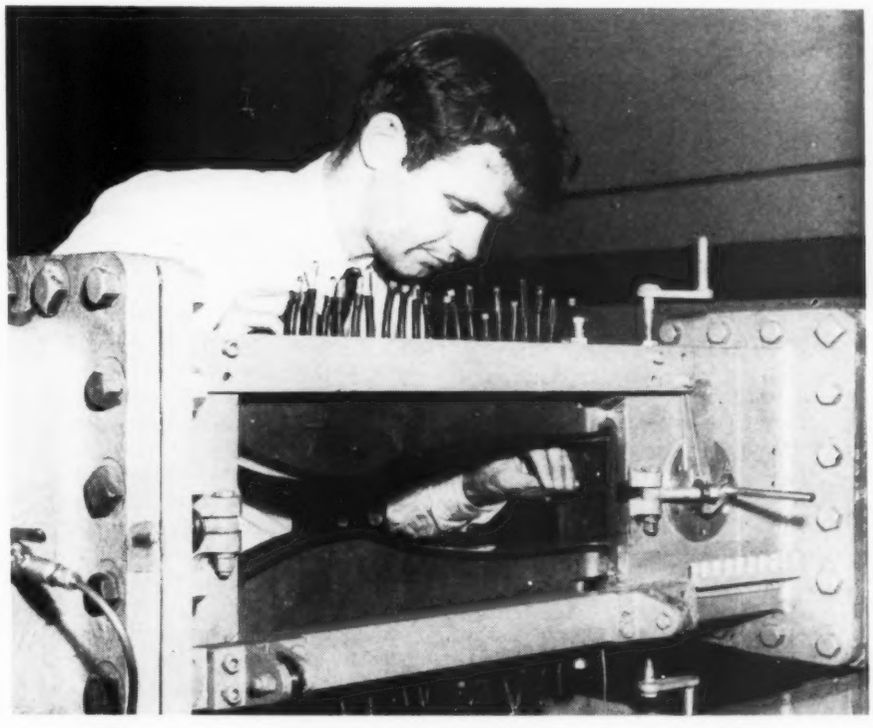
LAST-DITCH PLANS—Two moves were underway, to preserve at least the core of the OTS program—but in both cases Congressional action is required, a fact which made the outlook for OTS rather dark.

The Commerce Department intended going before the Senate Appropriations committee with a request for a 2.8 million dollars to continue the OTS as presently constituted, according to John Green, OTS director. Original budget request had been for 3.4 million dollars, which was cut to 1.7 million dollars by the House Appropriations Committee, which in turn was cut to nothing on the floor of the House.

The Senate Appropriations Committee could have restored at least part of the OTS funds, but such a fund would have had to pass the Senate and then a House-Senate Conference.

FULBRIGHT BILL—Parallel with the move to secure funds for OTS were the hearings held on the Fulbright bill, S. 493, by the Senate Committee on Expenditures in the Executive Departments. This bill would give specific legislative authorization for Commerce to carry on the kind of program it now has in OTS under authority of wartime executive orders and the general authority of the Secretary of Commerce to promote industry.

Virtually all witnesses came out in



R. B. PEARCE, in charge of North American Aviation's supersonic wind tunnel, adjusts a model of a projectile nose in the test section. Basic research on airfoils and projectiles at simulated speeds from 950 to 2,500 mph. are being made in the tunnel. Tubes above and below the test section are for attaching manometer tubes for recording pressures.

favor of continuing a "clearing house of technical information," either in their original statements or under questioning by the committee members. Among those in favor of this were representatives of the Army, Navy, Department of Agriculture, small business organizations, universities, the American Chemical Society, and spokesmen for individual companies.

Blanket opposition to S. 493 came from Howard E. Blood, president of the Norge Division of Borg-Warner Corp., who testified as representative of the National Association of Manufacturers. NAM opposed the entire bill, emphasizing the danger of government invasion of private industry's field by providing advice, service, and assistance to inventors, and by sponsoring applied research projects on its own. However, Mr. Blood did agree that the idea of a central office to disseminate technical information derived from government sources.

Even if the information clearing house carries over into fiscal 1948, the present OTS research program, carried on by its Research and Development Division, will expire. Out of its fund of 1 million dollars which it had for research in 1947, about $800,000 has been committed in contracts signed or about to be signed. Funds earmarked for specific projects will still be available until exhausted—cancellations were not planned unless the agency needed funds to meet personnel commitments.

Foreign Reports

. . . . . from McGraw-Hill World News

I.S.O. Council Meets for First Time

Five international organizations made arrangements for cooperation with the new International Organization for Standardization at its meetings last month in Zurich, Switzerland, according to Howard Coonley, American president of the I.S.O. and chairman of the Executive Committee of the American Standards Association.

Representatives of the International Civil Aviation Organization, International Labour Organization, International Federation for Documentation, International Dairy Federation and the United Nations Educational Social and Cultural Organization discussed cooperation on standardization matters of mutual interests. A joint committee to promote such cooperation was appointed.

The I.S.O. Council approved a resolution presented by the International Electrotechnical Commission in which it agreed to serve as the electrical division of the 27 nations' international body. Under the agreement the I.E.C. maintains its name and technical procedures.

Mr. Coonley opened the meeting of the I.S.O. Council, on which 11 nations are represented by saying: "this movement and this meeting are of great significance to the reconstructions, the progress, and the future peace of the world.

"It is my conviction that the greatest assurance of permanent world peace can come from the unrestricted exchange of goods and services between the nations great and small.

"Certainly no means can be more effective in the reaching of this goal than the achievement in the fields of industry, commerce and social behavior."

Mr. Coonley urged the Council to dedicate its efforts to the advancement of industry and commerce throughout the world in order to raise the general standards of living and to promote the contentment of people of all nations.

Russian Engineering Societies Expand Activities

Two new engineering societies—covering precision instruments and refrigeration—have been organized in Moscow. Their formation brings the total number of engineering associations in the Soviet Union to 30, with more than 2,000 branches in industrial centers throughout the country. These societies include some 50,000 engineers in various fields, the main requirement for membership being works or inventions developed outside of their regular line of duty.

President of the Soviet Academy of Sciences Sergei Vavilov has been elected chairman of the precision instruments engineering society, which will establish branches in Kiev, Leningrad and other industrial centers. The current "five-year plan" calls for a sharp increase in the production of precision instruments, with at least 25 different branches of industry interested in new developments in this field. Progress in the food industry and contemplated expansion of refrigeration prompted refrigeration engineers to set up their own society.

To promote independent investigations and studies by their members the two new engineering societies, like all others, will sponsor local and national conferences at which members will deliver reports. They will also publish the works of members and organize a broad exchange of experience among the different industrial enterprises in their field. Last year, members of these societies contributed some 1,500 reports and investigations. Particularly high rating is given to a new method of metal welding which finds application on railways. Many industrial enterprises make use of the consultation services offered by the engineering societies.

The activities of all these associations are coordinated by the All-Union Council of Scientific Engineering and Technological Societies, which is headed by Academician E. A. Chudakov. This council recently formed a special committee for the dissemination of the latest technological information.

Russians Cast Steel Tools

A method for the casting of tools from any type of steel in special furnaces, has been developed by Soviet engineers. The installation includes a small arc melting furnace which consumes 5 kilowatts of power, with the current fed through an ordinary welding transformer. The melting of metal in this furnace takes only 20 minutes. The moulds for the tools are produced from quartzite and metal oxides from aluminum patterns. A fine-grained casting is obtained, resembling in structure billets-forged, rolled and thermal-treated. Waste products of machined high-speed steel such as shavings, clippings and scrap tools, can be used for the production of cast tools.

This installation has been put into experimental operation, and specimen batches of milling cutters and cutter plates have been produced.

MEETINGS

August 15-September 14
Canadian Mathematical Congress—Summer seminar, University of Toronto, Toronto, Canada.

August 21-22
Society of Automotive Engineers—West Coast Transportation and Maintenance Meeting, Biltmore Hotel, Los Angeles, Cal.

August 25-28
National Association of Power Engineers—Hotel Statler, Boston, Mass.

August 26-29
American Institute of Electrical Engineers—Pacific General Meeting, Hotel San Diego, San Diego, Cal.

August 28-September 13
British Engineers' Association—Engineering and Marine Exhibition, Olympia Bldg., London, England.

September 1-4
American Society of Mechanical Engineers—Fall Meeting, Hotel Utah, Salt Lake City, Utah.

September 2-5
American Mathematical Society — Summer meeting, Yale University, New Haven, Conn.

September 8-9
American Society of Mechanical Engineers—Industrial Instruments and Regulators Division, Chicago, Ill.

September 8-12
Instrument Society of America — Conference and Exhibit, Stevens Hotel, Exhibition Hall, Chicago, Ill.

September 15-19
Illuminating Engineering Society—National Technical Conference, New Orleans, La.

September 17-18
Society of Automotive Engineers—Tractor Meeting, Hotel Schroeder, Milwaukee, Wis.

September 17-26
National Machine Tool Builders' Association—Machine Tool Show, Dodge-Chicago Plant, Chicago, Ill.

October 2-4
Society of Automotive Engineers—Aeronautic Meeting, Biltmore Hotel, Los Angeles, Cal.

October 6-7
Packaging Machinery Manufacturers Institute—Fifteenth Annual Meeting, Hotel Sheraton, Springfield, Mass.

October 18-24
National Metal Exposition—International Amphitheatre, Chicago, Ill.

October 20-21
Society of Automotive Engineers—Production Meeting, Carter Hotel, Cleveland, Ohio.

October 20-22
American Society of Mechanical Engineers—Fuels Div., Joint Meeting with the Coal Division of the American Institute of Mining and Metallurgical Engineers, Cincinnati, Ohio.

October 20-23
American Institute of Mining and Metallurgical Engineers — Iron and Steel Div. and Institute of Metals Div., Annual Meeting, Stevens Hotel, Chicago, Ill.

October 20-24
American Society for Metals—Annual Meeting, Palmer House, Chicago, Ill.

October 20-24
American Welding Society—Annual Meeting, Sherman Hotel, Chicago, Ill.

October 21-25
Pacific Industrial Conferences—Concurrent with Pacific Chemical Exposition, San Francisco Civic Auditorium, San Francisco, Cal.

Casting Resin Used In Electronic Applications

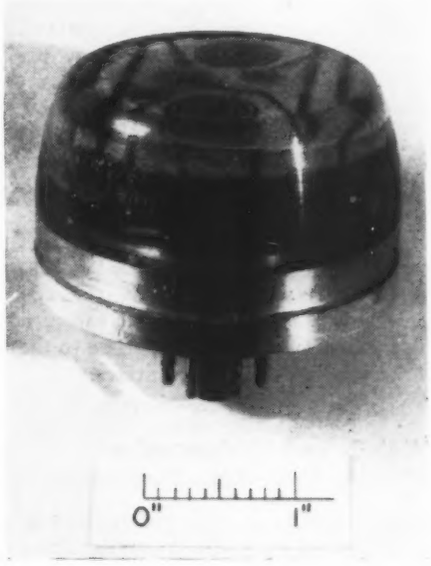
As a result of experience gained in the fuze-development program at the National Bureau of Standards, a new casting resin embodying properties of mechanical and electrical stability, has been formulated. Various applications at the Bureau indicate that, with slight modifications to suit the intended use, the new "potting" compound can be employed in many high-frequency devices requiring such mechanical-electrical insulation.

The most important properties desired of a casting resin when utilized at high frequencies in high-impedance circuits are low power factor, low dielectric constant, short polymerization period at low temperature and atmospheric pressure, high impact strength, small volume shrinkage on polymerization, dimensional and electrical stability, and low moisture absorption. The Bureau of Standards resin not only meets these requirements but fulfills the additional requirements of low viscosity and low surface tension, and hence can be poured through small openings.

When using this resin in devices having glass vacuum tubes, proper protection for the tubes, such as rubber jackets, should be provided to prevent possible cracking by thermal and mechanical shock. All sharp corners should be eliminated from any object which is to be cast, as strains set up at these points may cause crazing. It is advisable to continue the curing of the resin for a few days after the initial curing cycle.

When objects are to be suspended within the center of the casting resin it is advisable first to gel a portion of the casting resin and then to allow the gelled resin to support the sample. The mold is then filled completely with the casting resin and cured, after which the line of demarcation is invisible. Glass and properly lubricated metal molds have been used successfully. Silicone grease can serve as the lubricant.

The special features of this resin make feasible many new applications of electronic devices. By rigidly embedding electronic circuits or even complete plug-in sub-assemblies, the compound provides excellent electrical insulation as well as protection against rough handling and deteriorating atmospheric conditions. It is particularly well adapted for use with subminiature electronic equipment built by the printing techniques now under research by the National Bureau of Standards and by industry. Several practical applications of resin-potted circuits at the Bureau have given operation comparable to that of conventionally constructed devices. The resin should be especially useful in high-impedance control devices in heavy industry to provide adequate protection



A plug-in multi-stage electronic control unit is shown potted in the casting resin developed at the National Bureau of Standards. The new resin, which provides the required mechanical-electrical insulation for circuits, is particularly well adapted for use with subminiature electronic equipment.

against such conditions as vibration, acid fumes, high humidity, and salt spray. Other potential uses include the potting of components and subassemblies for radar equipment, hearing aids, portable radio transmitters and receivers, and numerous subminiature electronic control devices.

German High Temperature Steels Evaluated

GERMAN STEELS for high temperature uses are evaluated in terms of United States standards in a report now on sale by the Office of Technical Services, Department of Commerce. The report gives specifications for heat-resistant steels which the Germans used in aircraft turbine engines.

The 83-page report was prepared for the Air Materiel Command, Wright Field, Dayton, Ohio, by S. R. Puffer and W. L. Badger, technologists of the General Electric Company. Most of the report is a translation of specifications for special steels prepared by a Munich firm. The investigators were told that these specifications applied throughout Germany to materials used for the same purposes.

Many of the German steels described are inferior to comparable American steels and only a few are promising enough to warrant manufacture and testing, according to the report. Most of the comparisons with American steels refer to the standard steel specification numbers of the American Society for Testing Materials or the Society of Automotive Engineers.

Orders for the report (PB-50349; Evaluation of German Steels in Terms of United States Standards; photostat, $6; microfilm, $2; limited supply mimeographed, $2.25) should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order, payable to the Treasurer of the United States.

High-Speed Photography Aids Machine-Tool Designers

HIGH-SPEED PHOTOGRAPHIC STUDIES of cutting tools reveal that a rake angle of approximately 24 degrees is more efficient than a more acute one when machining steel, L. T. Weller of General Electric's Apparatus Manufacturing Department told delegates attending the recent American Society of Tool Engineers meeting in St. Louis.

At the 24-degree angle, the chip is rolled up with less crushing action and the chip flow is much smoother. In addition to showing the effect of various coolants on chip flow and the influence the speed of cutting has on chip flow, the use of photography produces much data of considerable value to designers.

The pictures were taken at 1000 frames per second, magnified, and then slowed down to 1/60th normal speed.

In one experiment, planing and milling machines were used to cut cast iron, brass, and mild steel, and the chip action, as it was influenced by rake and clearance angles, was observed to determine an optimum working condition as well as to find any irregular action resulting from improperly ground tools. Before the test, Mr. Weller reported, squares 1/32 inch apart were inscribed on the block of metal being processed. The shape of these figures after the test was an indication of the degree of chip compression. Results of this test show that the degree of rake angle determines the type of compression.

Applications of Precious Metals Shown at Finishing Exposition

UNUSUAL PIECES plated with the palladium and rhodium and other precious metals were displayed at the exhibit of the International Nickel Company at the Industrial Finishing Exposition of the American Electroplaters Society, held in the Municipal Auditorium, Detroit.

Rhodium, having the highest reflectivity of the platinum group metals and excellent hardness and abrasion resistance, was displayed in front surface mirrors, widely used in optical instruments of all kinds. Several pieces of micro-wave "plumbing" were displayed. These parts, used to "pipe" the electrons through the various phases of radar operation, are first silver plated to secure the electrical properties required and the silver is protected against oxidation by a plating of palladium. Radar tuning devices including a precision wavemeter and a coupling loop employing silver plate, palladium plate and rhodium plate, with constrictor springs of a high palladium alloy were loaned for the exhibit by Hazeltine Electronics Company, Little Neck, Long Island.

A series of projection mirrors prepared by Bart Laboratories, of Belleville, N. J., were displayed. These were rhodium plated on an undercoat of nickel. The small specimens are similar in construction to the 60-inch anti-aircraft search light reflectors used during the war. Rhodium's high reflectivity and resistance to elevated temperatures and oxidation make it ideal for arc lights or other severe conditions.

DISCUSSIONS AND COMMENTS FROM READERS

Torsional Shear Stresses In Deflection of Hollow Shafts

To the Editor:

Please accept the following comments regarding the Reference Book Sheet, "Torsional Deflection of Hollow Shafts", by Victor M. Kibardin, appearing in the April 1947 number of Product Engineering.

In the development of the charts no consideration has been given to the torsional shear stresses in the shafts. If we replace T in Formula (1) by $\frac{S_s 2I_p}{D}$ and solve the resulting equation for S_s we obtain

$$S_s = \frac{\theta G}{2} \cdot \frac{D}{L}$$

It is unlikely that the proportional limit in torsion will ever exceed 100,000 lb. per sq. in. Using this value of stress, $L/D = 2$ and $G = 11{,}000{,}000$ lb. per in. we obtain $\theta = 0.0364$. This is the upper limit of usefulness of Chart 1 when used without correction factors.

In the example given, the stress can be determined before any calculations of shaft dimensions are made. In the given case it will be

$$S_s = \frac{0.35 \times 11{,}500{,}000}{2 \times 5}$$
$$= 402{,}500 \text{ lb. per sq. in.}$$

This is so high that any further calculations would seem to be of little value. —ALEX. COWIE

Foote Bros. Gear and Machine Corporation

To the Editor:

In reply to Mr. Cowie's letter, the effects of torsional shear stresses on the deflection and physical dimensions of hollow shafts was deliberately omitted from the Reference Book Sheet, "Torsional Deflection of Hollow Shafts."

By combining the data of Chart 1 and "Parameter L/D Correction Factor F_P", a practical designer can and will find it possible to design shafts for $\theta = 1.0$ or $L/D = 55$. Mr. Cowie's contention that $\theta = 0.0364$ is the upper limit of usefulness of Chart 1 would be correct if the correction factor were neglected and all shafts

had the constant ratio $L/D = 2$.

The given example should be considered as qualitative, and is intended to emphasize the method of use of data, within the scope of the above assumptions.

I wish to thank Mr. Cowie for his comments. —VICTOR M. KIBARDIN

Corrections on Isolation of Vibration in Spring Mounted Apparatus—II

THE EDITORS AND THE AUTHOR are indebted to John J. Serrell of The Sharples Corporation for correcting and reporting errors in some of the equations presented in the article "Isolation of Vibration In Spring Mounted Apparatus—II," PRODUCT ENGINEERING, August, 1946, page 154. The corrections are as follows:

Bottom of third column, page 154, should read

"for rotation in the xz plane the following moments will act $\alpha\Sigma KX^2 =$ moment resulting from vertical deflection of the springs caused by rotation in the xz plane."

First column, page 155; the terms in parentheses on the right hand side of Equation (28) should be multiplied by α, thus

$$(\Sigma K X^2 + \Sigma C_z Z^2 - I_y \omega^2)\alpha$$

First colmun, page 155; in the last term of Equation (29), Z should be replaced by X, thus

$$\beta \Sigma C_y X$$

First column, page 156; in the equation for C_2 there are two errors, this equation should read

$$C_2 = I_y I_z \Sigma C_x + m I_y (\Sigma C_y X^2 + \Sigma C_z Y^2) + m I_z (\Sigma K X^2 + \Sigma C_z Z^2)$$

In the equation for C_3 the first two terms should be combined thus

$$C_3 = \Sigma C_x [I_y (\Sigma C_y X^2 + \Sigma C_z Y^2) + I_z (\Sigma K X^2 + \Sigma C_z Z^2)] + \ldots\ldots$$

In the equation for C_7, the sign before the term

$$I_z \Sigma C_y \Sigma K$$

should be plus, not minus.

Unionization of Engineers

To the Editor:

There have been a number of letters published on the pros and cons of the unionization of engineers, as well as the improvement of the status of the designer. Without going into the debatable phase of these matters, the writer would like to call attention to one phase of the engineer's problems, in his relation to his employer, and to society in general.

Except in the most enlightened organizations, which set up and maintain large development and research budgets, the average manufacturer classifies his engineering department as an item of overhead and as non-productive in his accounting system. As overhead, it is axiomatic that costs must be kept down, in competitive market, with the result that salaries are definitely controlled, the department kept at a minimum level, except under extraordinary conditions, and the stability of employment seriously impaired.

The sales department, including sales promotion and advertising, generally maintains elaborate charts showing the results it has accomplished in increasing sales. The result is that major personnel in sales and advertising departments are proportionately well compensated. This is particularly true as the men can readily shift from one organization to another without difficulty.

The men in charge of the production departments can readily show that they have increased production and reduced costs, and in this manner prove their worth to top management.

One question often lost sight of is the fact that neither the sales department nor the production department can function properly, unless they have a sound product to produce and sell; that is, unless the engineering department has done its job successfully. Where an outstanding product is produced competitively at low cost, sales will often increase rapidly. The engineering department will have been forgotten by that time. Where a product is poorly designed, and does not stand up, the company either absorbs a substantial loss, if it is strong enough, or goes out of business. In either case the engineer finds himself out of a job.

There is no single group in this country today which holds a greater influence over the national economy, national defense, and the well being of the people as a whole, than do the engineers collectively. Yet individually, and as a group, the recognition given them by society, financially or socially is nowhere near that accorded other individuals and groups.

Under present conditions the engineer's training both in school and in industry renders him more and more highly specialized as time goes on. The more highly specialized he becomes, the more vulnerable does he become to market changes in a particular industry. He is also more or less frozen to a particular job, or industry, with the result that his recognition and compensation are definitely limited.

Until engineers take a page out of the experience of other groups and effectively show their value to their organization and to society, their recognition will of necessity be limited.

—S. BERTRAND BARNARD

To the Editor:

I have read the article beginning on page 143 of the May, 1947, issue of Product Engineering, entitled "Unionization of the Engineering Profession." In it the writer, James W. Harley, Jr., deplores incompetency among engineers and suggests the forming of an American Engineers' Association.

I should like to call Mr. Harley's attention that considerable work has been done to correct the situations which he describes. Each of the 48 states have now inaugurated legislation providing for the registration of engineers. These registration laws set up standards of competency that must be met before the applicant can secure a license to legally practice the profession of engineering.

In addition, the National Society of Professional Engineers, with its member state societies and their local chapters, is set up to promote activities of many kinds, which will improve the status of the engineering profession. Mr. Paul H. Robbins, 1359 Connecticut Ave. NW, Washington, D. C., can furnish further information concerning the activities of the National Society of Professional Engineers.

—R. E. ALLEN
President, Dayton Society
Of Professional Engineers

Wants Commercial Literature Standardized

To the Editor:

During the past year and a half I have contacted many salesmen who have buried me under an avalance of circulars and pamphlets. I find that most of these concerns are printing such matter on any and every size paper that is conceivable.

To an engineer who is trying to build up a ready reference file of available data, most of this literature is just plain junk. Try to neatly file such matter, which is printed on 3 x 5 in. 8 x 10 in. or a x b in., and then find it in a hurry at some future time. I file most of this literature in the waste basket.

Why not start a campaign to standardize such matter. Why not use 8½ x 11 in. standard sheets? Also, why not standardize catalogs? Who wants a catalog that will not fit into a book case? —HORACE L. ASH
The W. J. Small Co., Inc.

Generation of the Conic Sections With Machine Tools

R. T. HINKLE
Department of Machine Design, Cornell University

Theorems from projective geometry can be duplicated by kinematic linkages for the generation of the ellipse, hyperbola and parabola. Basic machine dimensions are analyzed and the conversion of design dimensions of parts into machine settings for production is described.

CONIC sections can be generated by machines in a manner analogous to that of generating involute gear teeth by a rack-type cutter or to that of generating the involute helicoid on a worm thread with a flat-faced grinding wheel. The line or plane swept by the cutting tool is caused to move as the tangent to the profile, the envelope described by successive positions of the tangent being the desired curve or surface.

A conic section by definition is the intersection of a circular cone and a plane. The ellipse, the hyperbola and the parabola are the conic sections of interest here. The theory underlying the generation of these curves by machines is based on two theorems from projective geometry. See, for example, *Elements of Projective Geometry* by Cremona, page 254, third edition.

THEOREM I. If a right angle moves in its plane in such a way that its vertex describes a fixed circle, while one of the arms passes always through a fixed point, the envelope of the other arm will be a conic section concentric with the given circle, and having one focus at the fixed point. The conic is an ellipse or a hyperbola according as the given point lies within or without the given circle.

THEOREM II. If a right angle moves in its plane so that its vertex describes a fixed straight line, while one of the arms passes always through a fixed point, the other arm will envelop a parabola having the fixed point for the focus and the fixed straight line for the tangent at the vertex. The fixed point or focus must not lie on the chosen fixed straight line.

Kinematical schemes for generating the ellipse, hyberbola and parabola in accordance with the foregoing theorems are illustrated in Figs. 1(*A*) (*B*) and (*C*), respectively. A curve that looks like a conic but actually is a conic less a constant dimension measured normal to the curve will be generated if the plane of the cutter is advanced, say to a position *l-l*, Fig. 1(*A*). This property of parallel curves might be applied in allowing for roller radius in the generation a conic-section cam to operate with a roller follower. Or templates with an allowance for thickness of sheet metal might be made in this manner. Solids of revolution can be made by rotating the work during the machining operation.

A curve that is larger than a conic by a constant dimension measured normal to the curve would be generated by withdrawing the cutting surface to some position *m-m*. Thus a conic could be roughed out just slightly oversize before finish grinding exactly to size.

Machine Dimensions and Settings

Standard equations in rectangular coordinates of the conic sections can be used in designing machines to generate them. Let a and b represent the major and minor diameters of an ellipse, then the standard equation for this conic is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \qquad (1)$$

Three fundamental dimensions that make the machine adjustable for generating different ellipses are the radius of the fixed circle, or a, the position of the fixed point (focus) relative to the center of the fixed circle and the point of contact between the tool and the envelope. The eccentricity of an ellipse, always less than unity, and the radius a establish the position of the focus; namely,

$$a\,e = a\,\sqrt{1 - (b/a)^2} \qquad (2)$$

Note is made that the position of the point of contact of the tool and the work varies as the curve is generated, whereas the dimensions a and ae remain fixed while any given ellipse is described. The latter therefore are dimensions that can be regarded as basic machine settings. They might be set by means of graduated scales or dials.

Machine tools based upon these linkages can be designed in many different ways. One scheme using a slotted disk supported at the edges is shown in Fig. 3. Hyperbolas and ellipses are generated by turning the disk that moves the vertex of the right angle in a circle. Parabolas are generated by fixing the disk and moving the vertex along the slot.

In all probability the circle that is regarded as fixed by the theory would have motion in a real machine. In other words the kinematic links would be inverted so as to make stationary the tool carrying link. The relative motion, which is the primary concern of this discussion, remains unaltered.

In practice the conics are not always stated in equation form. Airplane surfaces, for example, are often composed of segments of the conic sections but equations to describe them are unknown and must be determined. Such sections may be defined by two sides and the included angle of a triangle. Thus the given information insofar as the conic is concerned con-

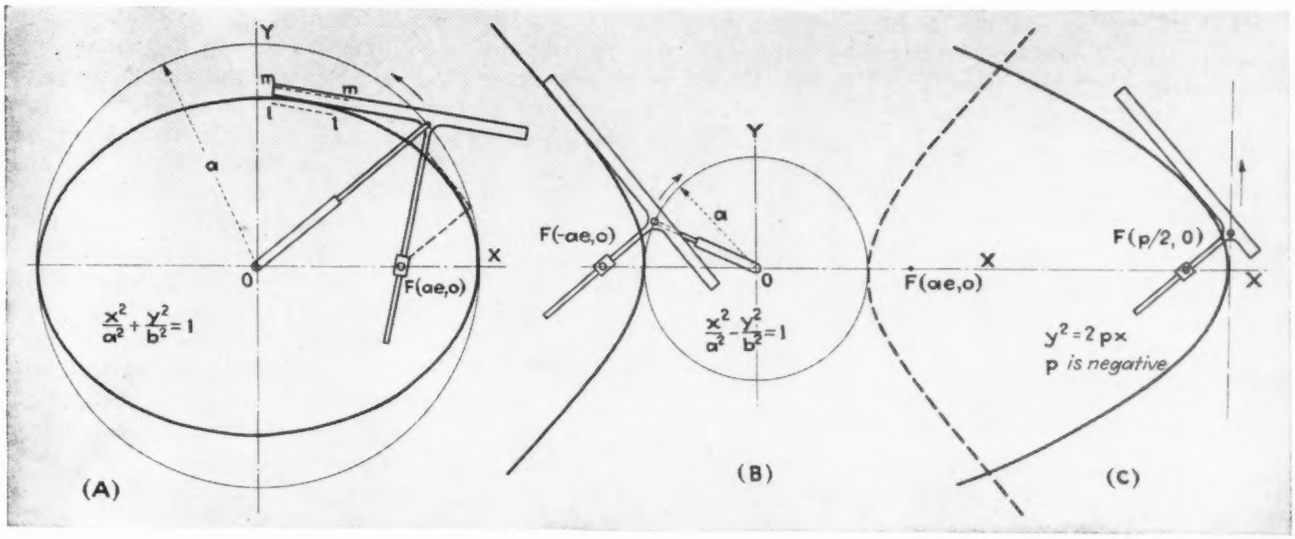


Fig. 1—Kinematic schemes for generating (A) ellipse, (B) hyperbola and (C) the parabola as the envelope of a straight line.

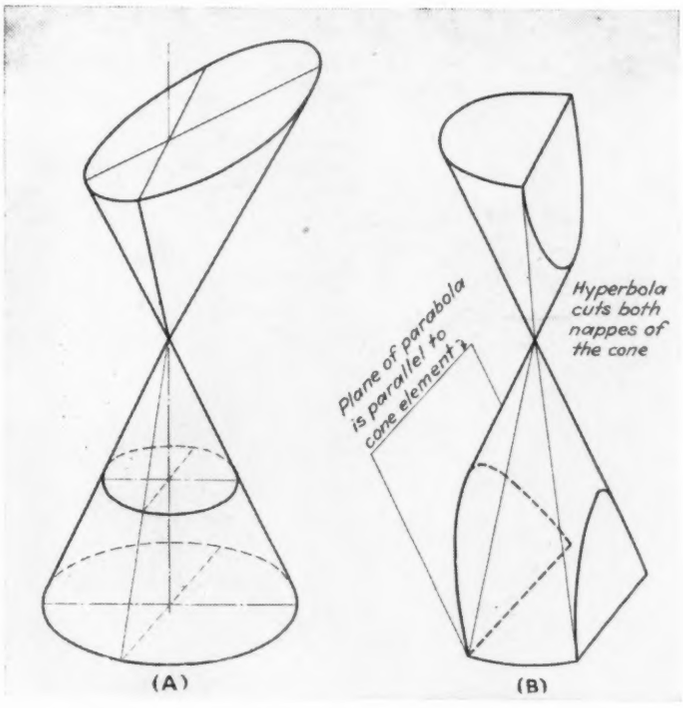


Fig. 2—Conic sections formed by intersection of plane and circular cone. Circle in (A) is special case of the ellipse.

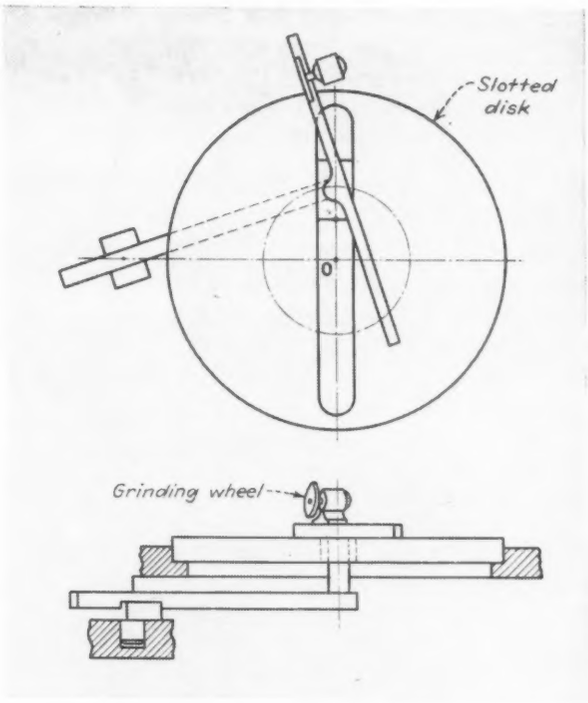


Fig. 3—Mechanical scheme whereby several machine settings could be arranged to generate all conics.

sists of two points on the curve and the directions of the tangents at these points—in all four requirements are given. In general, five conditions are required completely to define a conic. These five conditions are expressed by an equation of the second degree in two variables x and y; namely,

$$A_1 x^2 + B_1 x y + C_1 y^2 + D_1 x + E_1 y + F_1 = 0 \quad (3)$$

Now this general equation of the second degree includes not only the ellipse, hyperbola and parabola but also the circle, a point, one straight line and two intersecting straight lines. The last three comprise the so-called degenerate conics. The circle is a special case of the ellipse, such that b equals a. If desired, a machine constructed on the plan of Fig. 3 could be used to generate curves that are combinations of the conics, circular arcs and having discontinuous tangents at one or more points. Settings for the circular and straight line portions are obvious from the diagrams and are therefore excluded from further consideration.

With these exclusions, Equation (3) represents an ellipse, a hyperbola or a parabola according as B^2_1 minus $4A_1C_1$ is less than zero, greater than zero or equal to zero. Suppose the curve is an ellipse. From analytic geometry the terms of first degree drop out if the ellipse is referred to rectangular axes with the origin at the center of the ellipse. Assume these new axes to be U and V, parallel to the X and Y axes respectively, then Equation (3) reduces to

$$Au^2 + Buv + Cv^2 + F = 0 \quad (4)$$

By a rotation of the axes the co-

efficient of the uv-term can be reduced to zero. Transformation equations suitable for this rotation can be written by inspection from Fig. 4(A) as

$$u = y \sin\theta + x \cos\theta$$
$$v = y \cos\theta - x \sin\theta \qquad (5)$$

Substituting these values of u and v into Equation (4), gathering the coefficients of x^2, y^2 and xy and setting the coefficient of the xy-term equal to zero, there is obtained

$$A' x^2 + C' y^2 + F' = 0 \qquad (6)$$

the angle θ required to transform Equation (4) to Equation (6) is given by

$$\tan 2\theta = B/(C - A) \qquad (7)$$

Now the quantities A plus C and B^2 minus $4AC$ are invariants, that is they are properties of the curve that are independent of the choice of the axes; hence

$$A + C = A' + C' \quad \text{and} \qquad (8)$$
$$B^2 - 4AC = -4A'C' \qquad (9)$$

The standard form of the ellipse, as stated in Equation (1), can be obtained from Equation (6) by dividing through by F'. Figs. 4(B) and (C) illustrate a pole, the corresponding polar and a pair of conjugate diameters of an ellipse. A diameter passes through the middle points of a family of parallel chords. All the diameters pass through the center, of course. Conjugate diameters are pairs in which one diameter passes through the middle points of the chords parallel to the other.

By definition, the polar of a pole P_0 is that chord, the points of which divide harmonically any line drawn through the pole and to intersect the ellipse. The tangents from the pole touch the ellipse at the extremities of the chord. A diameter extended passes through the middle point of the chord. Thus P_3 is the mid-point of P_1 P_2, Fig. 4 (C). The diameter Q_1 Q is divided internally by P_3 and externally by P_0. By the definition of harmonic division

$$P_3Q/Q\,P_0 = Q_1P_3/Q_1P_0 \qquad (10)$$

Suppose P_3 Q and Q P_0 are represented by h and by H minus h respectively, then

$$Q_1\,P_3 = \overline{2O\,P_3} + h$$
$$Q_1\,P_0 = \overline{2O\,P_3} + h + H \qquad (11)$$

If these quantities are substituted into Equation (10), there is obtained

$$OP_3 = \frac{h^2}{H - 2h} \qquad (12)$$

This equation makes possible the location of the center of the ellipse when distance h, the lengths of the tangents and the angle between them are known. Since the two tangents account for only four (two points and two slopes) of the five conditions required to define an ellipse, the fifth can be defined by a choice of the dimension h. An infinitude of ellipses is possible, all tangent to the lines P_0P_1 and P_0P_2 at P_1 and P_2, respectively.

With point O on the half diameter OQ determined, the points P_1, P_2 and Q can be readily expressed as u and v coordinates of OQ as the U-axis. The coordinates for these three points when substituted into Equation (4) fix the parameters A, B, C and F. The invariants, Equations (8) and (9), simplify computations to effect rotation through an angle θ to yield Equation (6), or the more

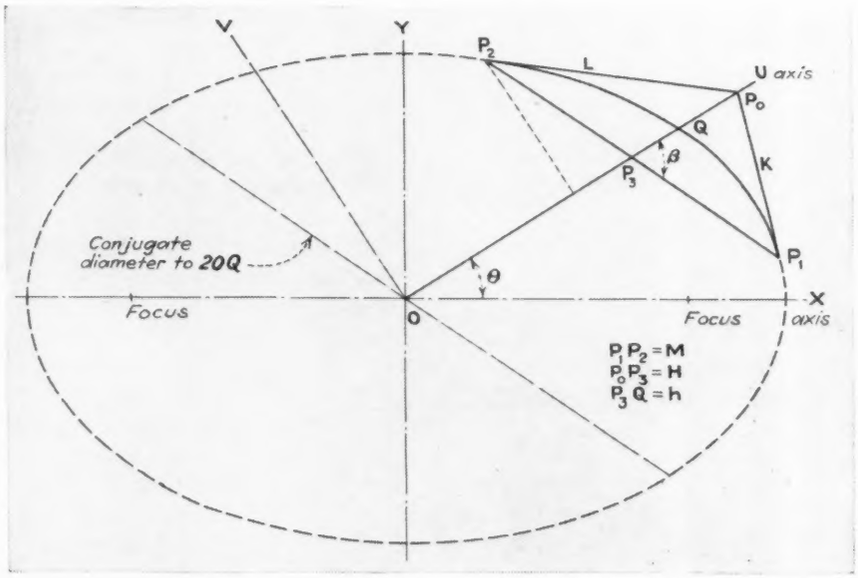


Fig. 5—An ellipse established by tangents P_0P_1 and P_0P_2 and point Q on curve.

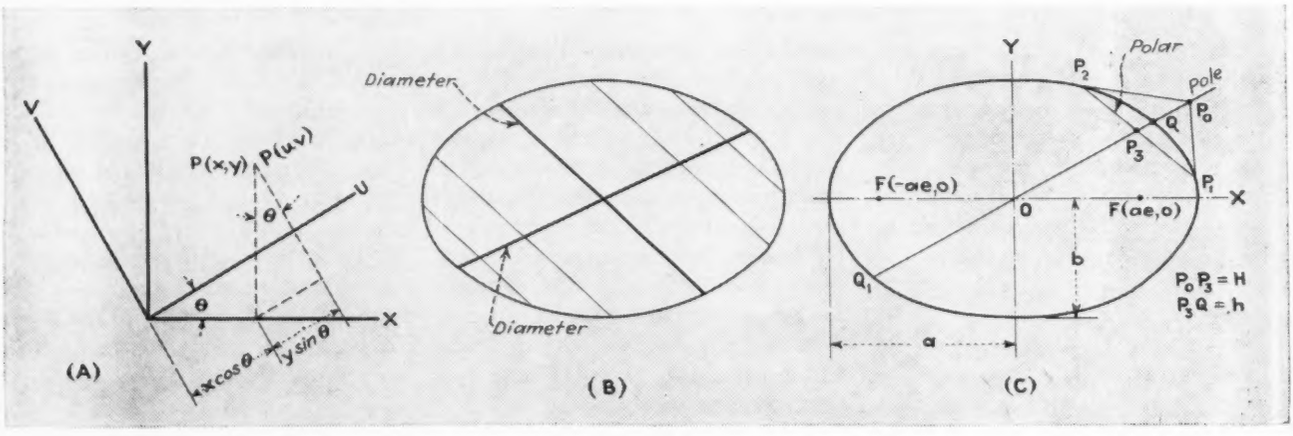


Fig. 4—(A) Geometrical relations for rotation of axes; (B) Diameters of an ellipse; (C) A pole and polar of an ellipse.

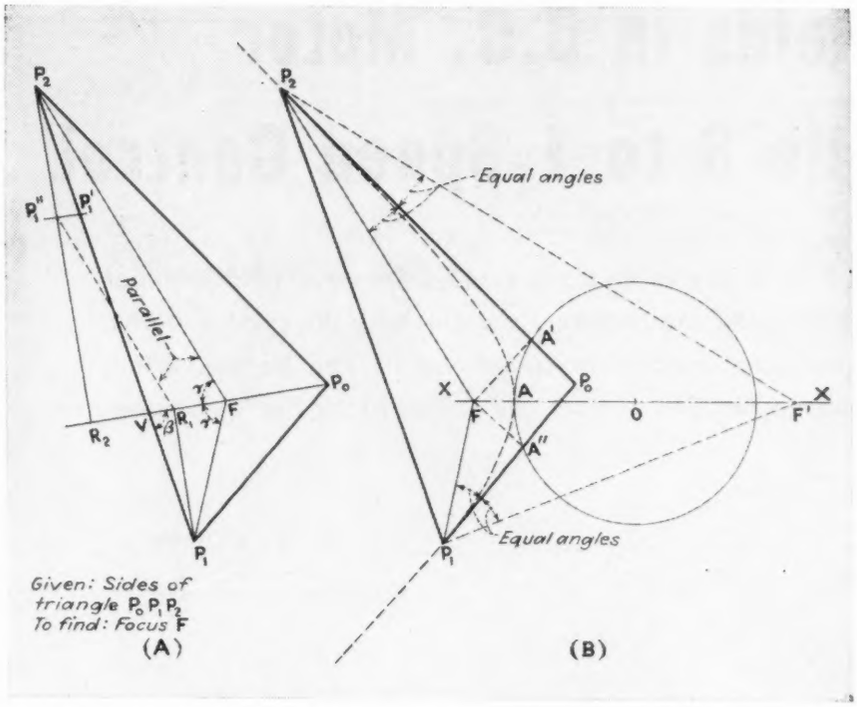


Fig. 6—Graphical solution is based on theorem that one of the bisectors of the angle that a chord subtends at a focus passes through the pole of the chord.

usual form Equation (1). An example will illustrate the procedure.

EXAMPLE. Let K equal 3.4 in., L equal 5 in. and M or P_1P_2 equal 7 in., Fig. 5. Assume the ellipse corresponding to h equal 1.11 is desired. By trigonometry

$$H^2 = (K^2 + L^2)/2 - M^2/4 = (11.56 + 25)/2 - 49/4 = 6.03$$
$$H = 2.4556$$

Putting these values of h and H in Equation (12) gives

$$OP_3 = \frac{h^2}{H - 2h} = \frac{1.2321}{0.2356} = 5.2295$$

From the law of cosines

$$\cos\beta = \frac{M^2/4 + H^2 - K^2}{MH} = \frac{12.25 + 6.03 - 11.56}{17.1992} = .039073$$
$$\beta = 67^\circ 0' \qquad \sin\beta = 0.92050$$

With respect to the half diameter OQ as the U-axis, the coordinates of P_1, P_2 and Q are

$$P_1\,(u_1, -v_2) \equiv P_1\,(6.5970, -3.2218)$$
$$P_2\,(u_2, v_2) \equiv P_2\,(3.8620, 3.2218)$$
$$Q\,(u_Q, 0) \equiv Q\,(6.3395, 0)$$

These coordinates upon substitution into Equation (4) give

$$F/A = u_Q^2 = -40.189$$
$$B/A = (u_1 - u_2)\,v_2 = 2.7350/3.2218 = 0.8489$$
$$C/A = (u^2_Q - u_1u_2)\,v^2_2 = (40.189 - 25.478)/10.380 = 1.4172$$

These ratios of the constants, F/A, B/A and C/A can be put into Equation (4) giving

$$u^2 + 0.8489\,uv + 1.4172v^2 = 40.189$$

To transform this equation to the standard form, the invariant relations, Equations (8) and (9) are used, giving

$$A + C = 1 + 1.4172 = A' + C'$$
$$B^2 - 4AC = 0.72065 - 5.6688 = -4A'C'$$

A solution of these equations is

$$A' = 0.73566 \text{ and } C' = 1.6815$$

so that Equation (6) takes the form

$$0.73677x^2 + 1.6815y^2 = 40.189$$

This equation is divided by 40.189 to get the standard form as

$$x^2/54.63 + y^2/23.9 = 1$$

Graphical Solution

The Machine settings can also be determined graphically. Assume the same conditions as before, that is, that a conic is to be tangent to two lines P_2P_o and P_1P_o at the points P_2 P_1, Fig. 6. The fifth condition is determined when it is assumed that the focus lies on a third line through P_o. This line intersects P_2P_1 at some point V. The location of F on the line VP_o is determined from the condition that angles VFP_1 and VFP_2 must be equal.

Suppose these equal angles are denoted by γ, Fig. 6(A). One way of finding the position of F graphically is as follows: Draw perpendicular lines P_1R_1 and P_2R_2 to line P_oV. Lay off P_2P_1' equal to P_1V and draw $P_1'P_1''$ parallel to P_oV. A line parallel to $P_1''R_1$ passing through P_2 intersects P_oV at the desired focus F. An analytical proof of the construction is readily established.

From triangle VFP_1

$$P_1V \sin\beta = R_1F \tan\gamma \qquad (13)$$

and from triangle VFP_2

$$P_2V \sin\beta = (R_2R_1 + R_1F) \tan\gamma \qquad (14)$$

Eliminating $R_1F \tan\gamma$ from Equations (13) and (14) gives

$$\tan\gamma = (P_2V - P_1V) \sin\beta / R_2R_1 \qquad (15)$$

The numerator of Equation (15) is equivalent to R_2P_1'' so that angle $R_2R_1P_1''$ represents angle γ. When angle β approaches a right angle, this part of the graphical solution becomes inaccurate, under which conditions Equations (13) to (15) can be used to compute the VF dimension.

The other focus F' is determined by reflecting rays FP_2 and FP_1, Fig. 6(B). In this example the rays must be extended back to give an intersection, for the conic is a hyperbola. The center O is midway between F and F'. Perpendiculars are drawn from F to the tangents. A circle with center at O and radius OA' will pass through A'' and will locate A. The dimensions FA and OA are the basic machine settings. The equation of the hyperbola is

$$\frac{x^2}{(AO)^2} - \frac{y^2}{(FO)^2 - (AO)^2} = 1$$

Similar constructions can be made if the conic is an ellipse or parabola. The few transformations that have been illustrated do not by any means exhaust the variety of ways of defining the conic sections. For example the fine conditions might be five points through which the conic must pass, or five lines to which the conic must be tangent, or any combination thereof. The equations for these conditions can be readily derived by the foregoing methods.

Dual Fields in D.C. Motor Provide Simple 8 to 1 Speed Control

A semi-standard type of d. c. motor using a main and differential field provides an 8 to 1 speed range with good regulation. How and why the system works, performance data, how standard adjustable speed motors can be converted, typical control circuits, and application factors are included in the discussion.

R. W. MOORE
Motor Engineer,
Westinghouse Electric Corporation

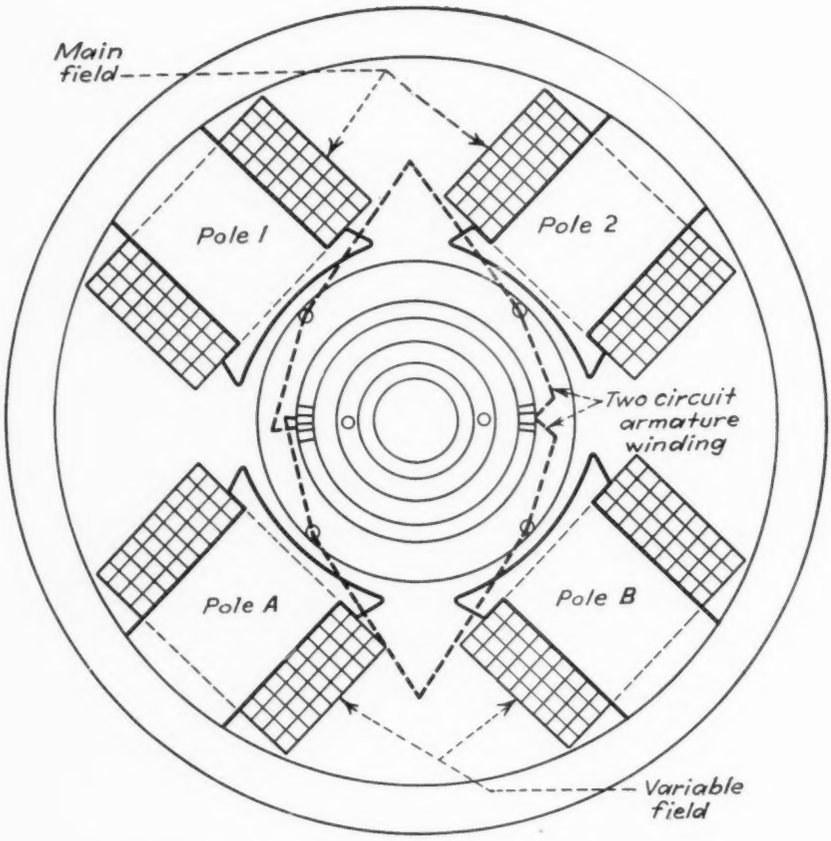


Fig. 1—The 8 to 1 speed range motor uses two separate magnetic circuits produced by a main field and a variable field.

A SPEED range of 8 to 1 by field control of a d.c. motor can be obtained by using two separate magnetic circuits and a two circuit armature winding. Such a motor differs only slightly from a conventional d.c. motor as shown is in Fig. 1. For simplicity, the interpoles are not shown in the sketch but interpoles are required for an 8 to 1 speed motor just as they are for a standard adjustable speed motor.

The 8 to 1 speed motor has special shunt fields connected as shown in the typical schematic diagram of Fig. 2. The shunt field F_1-F_2 is wound on poles 1 and 2 of Fig. 1 and form the main field. The second shunt field F_3-F_4 is wound on poles A and B of Fig. 1 and serves as the variable field. The main field is designed for full excitation voltage and the variable field is designed for half excitation voltage.

Both Fields Changed Simultaneously

To obtain an 8 to 1 speed range, both the main field F_1-F_2 and the variable field F_3-F_4 are changed simultaneously. The main field is varied from full field to approximately 60 percent full field, while the variable field is changed from full field in cumulative direction thru zero to that value of current in the opposite direction to obtain maximum speed. This is done by a rheostat in series with the main field and a potentiometer rheostat for the variable field as shown in Fig. 2. Both rheostats are operated from the same handle, and Fig. 3 shows the variation of field currents with speed.

The speed of such a motor changes with variations in field current for the same reason that any d.c. motor changes speed with changes in flux. That is, for any value of flux the speed must be such that the generated armature voltage equals the applied voltage minus the resistance drop in the armature circuit. In the motor shown in Fig. 1, there is no interaction between the magnetic circuits, 1 and 2, and the magnetic circuits A and B, provided that 1 and 2 are identical and A and B are identical. The conductors under poles 1 and 2 will have voltage generated in them proportional to the flux in the magnetic circuit and the same will be true of the conductors under poles A and B. However, this voltage will have a direction that is dependent on the relative polarities of A and B. Since a two circuit winding is used, the conductors under poles 1 and 2 are in series with the conductors under poles A and B. Therefore, the gen-

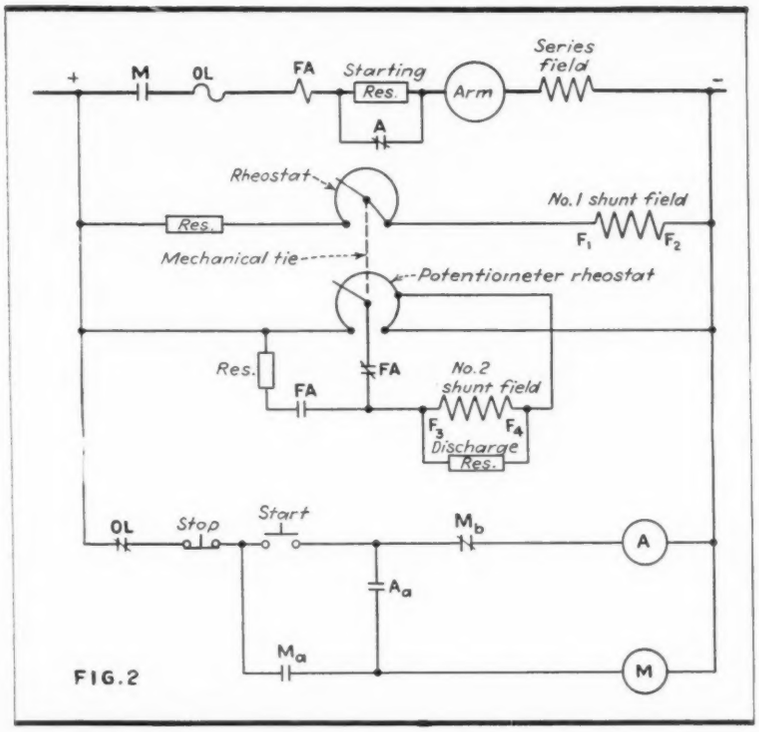


FIG. 2

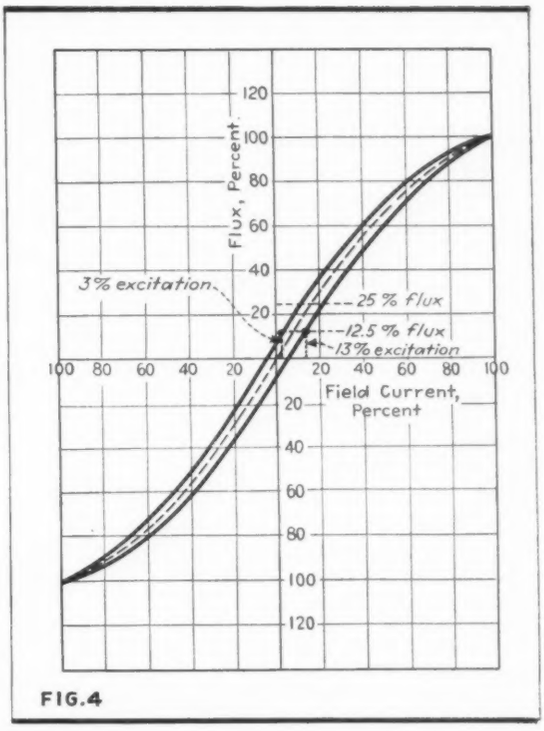


FIG. 4

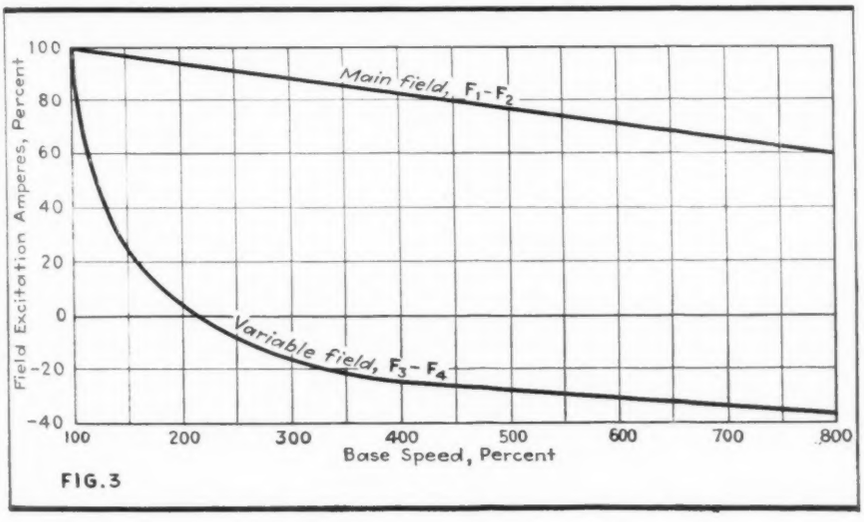


FIG. 3

Fig. 2—Schematic of typical control circuit for the 8 to 1 speed range motor showing the dual rheostats.

Fig. 3—Relation of exciting currents in the main and variable fields to speed from 100 to 800 percent.

Fig. 4—Hysteresis characteristic of a d.c. machine affects its residual flux.

erated voltage at the brushes is the algebraic sum of the voltage generated in these conductors in series, and a high speed can be obtained by reversing the direction of flux in poles *A* and *B*.

A review of the factors that limit the range of a standard adjustable speed motor helps to understand how the 8 to 1 range is obtained. The usual limiting factors are: Changes in residual magnetism, armature distortion, demagnetization of the main field by the armature, and increase in reactance voltage. These factors cause instability or poor commutation when the field of a motor is weakened beyond that required to obtain four times base speed. Since the main field is extremely weak the effect of these factors is intensified. Therefore, the operation of a standard adjustable speed motor under these conditions is generally unsatisfactory.

At eight-times base speed the flux of a standard adjustable speed motor is $12\frac{1}{2}$ percent of normal. In the typical hysteresis loop for a d.c. machine shown in Fig. 4, the field strength to obtain $12\frac{1}{2}$ percent flux may be as low as 3 or as high as 13 percent of normal depending on the magnetic condition of the machine. Therefore, any change that affects the residual of the machine would change the flux appreciably at these low field strengths, and also the speed.

Because the armature ampere turns acting at the pole tips are many times those of the weakened main field, there would be negative flux under one pole tip and positive flux under the other. This flux spreads into the interpolar zone increasing the reactance voltage. The center of commutation may change possibly because of slight shift of the brush in the holder or from the effective compensation changes resulting from variations of residual magnetism of the commutating pole magnetic circuit. This results in a direct demagnetizing action on the main field. As small as this effect is, at extremely weak main field strength the relative change in flux, and therefore in speed, is considerable.

The reactance voltage of a d.c. machine and the compensating commutating voltage are both directly proportional to speed. However, even with interpoles, there are limitations to the reactance voltage that can be

commutated successfully. These limitations exist also for the 8 to 1 speed range motor. However, by maintaining a strong main field, increases in reactance voltage caused by factors other than speed, such as armature distortion ampere turns, is kept to a minimum.

The important fact is that if the fields can be kept strong the factors that usually limit the range of an adjustable speed motor have little affect. This is done in the 8 to 1 motor.

Standard Motors Can Be Modified

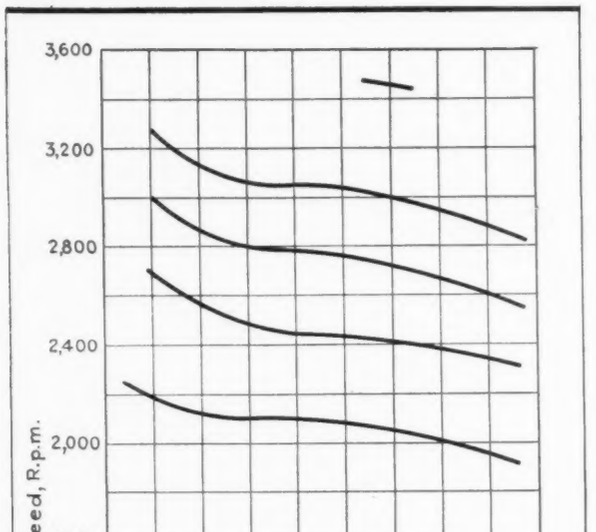
It is possible to modify a standard, four pole, adjustable speed motor by changing the fields and obtain an 8 to 1 speed. This is an important advantage of the development because it is less expensive to do this than to design and build a new motor. However, the top speed of such a modified motor is limited by the structural strength of the rotor and this in turn determines the speeds at which the 8 to 1 range can be obtained. If the base speed must be lowered to obtain the 8 to 1 range then the size and cost of a given rating is increased.

During the test of a motor over an 8 to 1 speed range, the limiting factor was commutation at the top speed. Regulation curves of an 8 to 1 speed motor are shown in Fig. 5. As the safe mechanical limit of the motor tested was 3,600 r.p.m. the full load point at eight times base speed was the only one taken. Therefore, a complete regulation curve at this speed could not be plotted. Over the range plotted good regulation was obtained. This is obtained by reducing the main field current as shown in Fig. 3. This reduction in main field strength also keeps down the iron losses in the armature portions, which are at high flux density at high speed. Stable operation and satisfactory commutation were obtained over the 8 to 1 range.

During these tests, neither excessive vibration nor shaft deflection from unbalanced magnetic forces were apparent. In a d.c. machine the air gap is comparatively large and the shaft is relatively stiff. Thus, even a large unbalanced force results in a deflection small in proportion to the air gap dimensions. By using the bottom two poles as the variable field the weight of the armature counterbalances a part of the unbalanced magnetic force. At eight times base speed the average air gap densities to the two magnetic circuits differ by $12\frac{1}{2}$ percent. Although this difference results in an appreciably unbalanced force, it is still not strong enough to cause shaft deflection or create vibration.

Relatively Simple Control

The control for the 8 to 1 speed motor is similar to that required for the conventional d.c. adjustable speed motor. This is also true when dynamic braking is required or the motor is to be used for reversing serv-



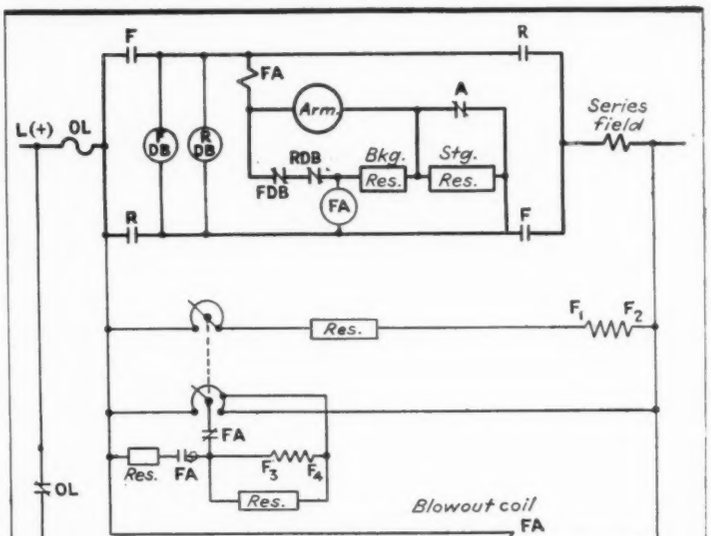


Fig. 6—Schematic diagram for reversing and dynamic braking of an 8 to 1 adjustable speed type motor.

Fig. 5—Reasonably good regulation is obtained from this 5/7.5 h.p., 230 volt, 8 to 1 speed range motor, with 450 r.p.m. base speed and 3,600 top speed.

ice as shown in Fig. 6. Antiplugging means must be provided either by construction of the main line contactors or by a special relay. Even though the variable field is differential with respect to the main field this motor cannot be plugged by reversing the main field. If attempted at the eight times base speed and assuming the main field flux could be reversed instantaneously, there would be a voltage approximately four times line voltage generated in the conductors under the main field in such a direction as to add to the line voltage instead of oppose it. In the conductors under the variable field, the voltage is approximately three times line voltage and also in a direction as to add to the line voltage. Thus eight times line voltage exists to cause current to circulate through the motor and the motor will flash over.

The 8 to 1 speed range motor can be used to best advantage for those applications requiring constant horsepower over the speed range. Wind-up drives and spindle drives for machine tools such as lathes and grinders have this characteristic. The magnetic conditions of the 8 to 1 speed motor are radically different from those of the conventional adjustable speed motor. It still is a constant horsepower device because the net positive torque output depends on the interaction of the current and the net positive flux in the motor. A tapered horsepower rating may be given to the 8 to 1 speed motor when the increased ventilation at higher more than offsets the added losses at these speeds, just as such a rating can be given the conventional adjustable speed motor.

Where the characteristics of the load are such that constant torque is required over the speed range, the 8 to 1 speed motor offers no advantages as compared to the conventional adjustable voltage drive or the series variable voltage drive. For this type of load the horsepower required varies directly with speed. Since the 8 to 1 speed motor is essentially a constant horsepower drive it must be designed for the maximum horsepower required by the load that occurs at maximum speed; therefore, it will be eight times too large at low speed. Where a tapered rating can be used this factor can be reduced. For a constant torque load assuming the most advantageous speeds and an available source of d.c. for the 8 to 1 speed motor, this motor and its associated control will occupy less space but its cost will be higher than the control, the motor-generator exciter set, and d.c. driving motor of a conventional adjustable voltage drive. For a constant horsepower load the comparison will be most favorable for the 8 to 1 speed motor. Thus a general comparison may be misleading since the characteristics of the load are the factors that determine the most suitable drive for a particular application.

64 to 1 Speed Range Combination

When the conventional 8 to 1 adjustable voltage drive is used with the 8 to 1 speed motor a total speed range of sixty-four to one can be obtained. Without complicated control this drive would have good regulation over this range and should be suitable for all applications requiring wide speed range without precise control.

The 8 to 1 speed motor does not replace the conventional adjustable voltage drive but complements it. Perhaps the most important advantage of this motor is that its construction differs only slightly from that of a conventional d.c. motor. This means that the cost and availability differ only slightly from the conventional d.c. motor thus making it possible now to obtain the advantages of a wide speed range for many applications to products and machines.

German Potentiometer Gives Precise Readings

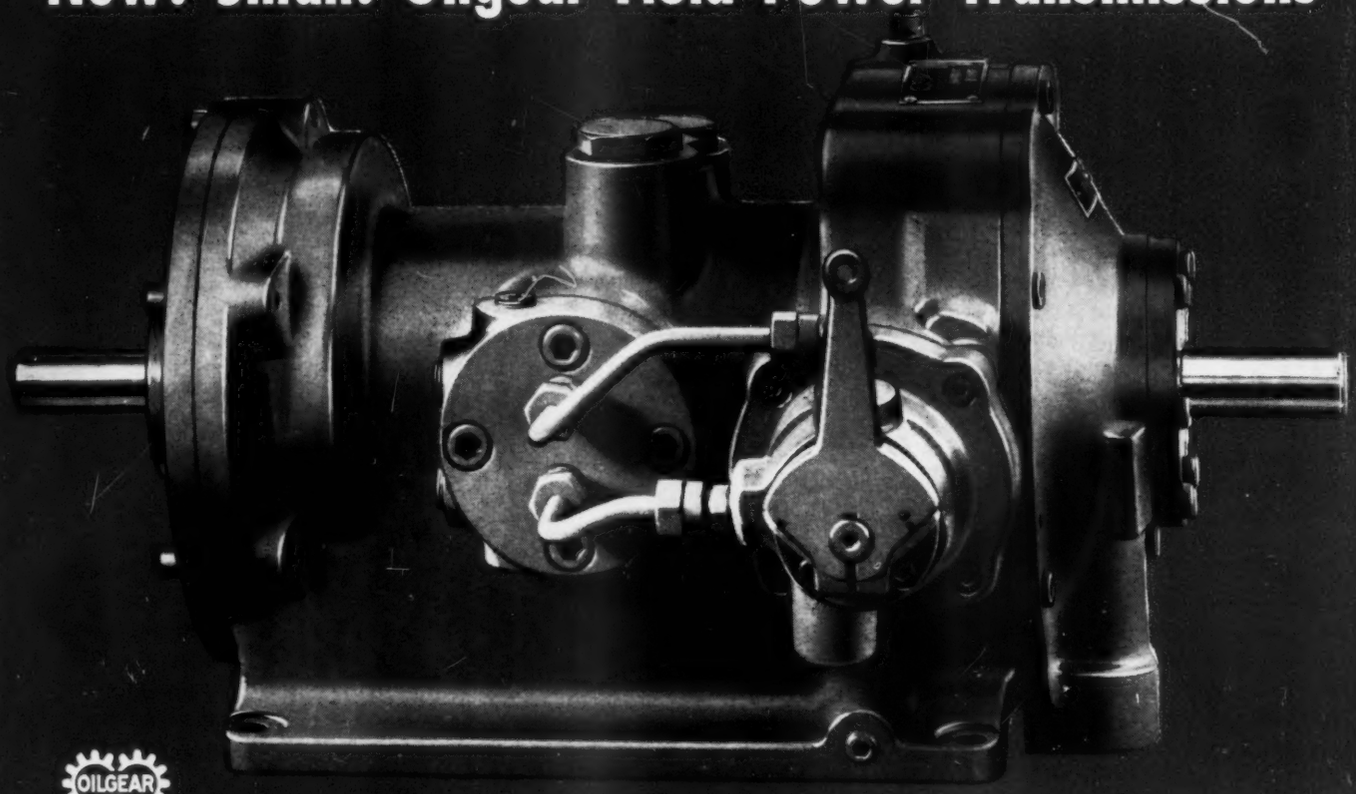
A NEW TYPE OF POTENTIOMETER that can compare or measure electromotive forces much more precisely than instruments wound with the finest wire was invented in Germany during the war, according to a report on sale by the Office of Technical Services, Department of Commerce. OTS has obtained an experimental model of the complete potentiometer. Manufacturers and technical organizations interested in examining the model of the potentiometer should address requests to Lloyd R. Worden, Office of Technical Services, Department of Commerce, Washington 2, D. C. The report was prepared by Lloyd R. Worden and Henry N. Droge for the Combined Intelligence Objectives Sub-Committee. Mr. Worden is chief of the aeronautics and automotive unit of OTS' technical industrial intelligence division; Mr. Droge is manager of the Kollsman Instrument Division of the Square D Company, Elmhurst, N. Y.

The potentiometer was developed by Uher and Company, Munich. The resistance unit consists of two layers folded together in accordion manner and then compacted under heat into a solid mass. One layer is a very thin strip of paper; and the other, an equally thin strip of Konstantan foil —an alloy of 60 percent copper and 40 percent nickel. The resistance unit can be made in any width or shape and can be milled to obtain straight-line, sinusoidal, or similar electrical characteristics.

The side selected for the contact path contains alternate edges of paper and foil. Each millimeter of the path can give as many as 40 gradations in resistance values—many more than the number obtained in the best wire-type potentiometers, the report indicates. A spring-loaded contact arm moves over the polished contact path with virtually no friction, thereby permitting the potentiometer to be coupled with any low-power precision instrument. However, the slightness of the contact does not prevent the resistance unit from receiving and handling comparatively large current loads.

Orders for the report (PB-464, "Precision Potentiometer", photostat, $1; microfilm, 50 cents) should be addressed to the Office of Technical Services, Department of Commerce, Washington 25, D. C., and should be accompanied by check or money order, payable to the Treasurer of the United States.

New! Small! Oilgear Fluid Power Transmissions



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These transmissions efficiently convert a *constant* rotary motion into accurately controllable *variable* rotary motion. They provide smooth, stepless, uniform acceleration from zero to maximum in either direction. Their positive drive is not affected to any appreciable degree by variations in load. They use little power, and always in proportion to work done.

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September 17-26

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Vector Analysis of Epicyclic Gear Trains

LEO AVONDOGLIO
Curtiss-Wright Corporation

THE USE of velocity vectors gives a simple, direct approach to the solution of compound epicyclic gear trains by using a graphical solution. The desired ratio and direction of rotation can be approximated before making a mathematical check by shifting gear centers and changing diameters on the layout.

The letter symbols used that are not defined denote the pitch diameters of the gears.

A = effective radius of arm, in.
I_c = instantaneous center
V = linear velocity, in. per sec.
ω = angular velocity, radians per sec.

The analysis of epicyclic gear trains, see Figs. 1 and 2, by means of velocity vectors is based on three theorems:

1. The velocity of any point on a rotating body is equal to the angular speed of the body multiplied by the distance between the center of rotation and the given point.

2. The velocities of any two points on a rotating body are proportional to the distances between the center of rotation and the points being considered.

3. The point of contact of a body rolling on another body has the same velocity related to each body. When one of the bodies is stationary, the point of contact is the instantaneous center of the rotating body.

The diagram can be drawn by considering the gear elements that are in mesh as made up of levers. Such a system of levers would give a rigid linkage. If the points on the levers are assumed to remain at a constant vertical distance from the instanta-

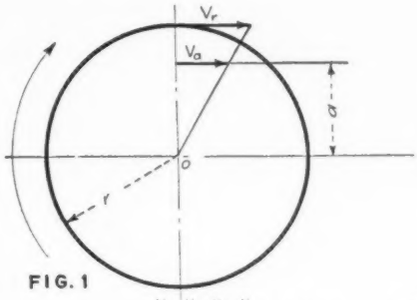


FIG. 1

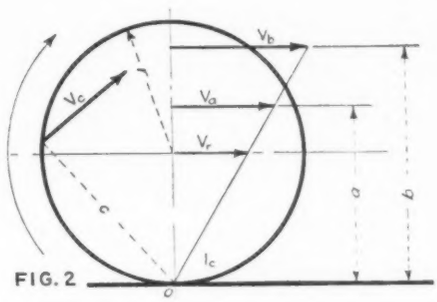


FIG. 2

$\frac{V_b}{b} = \frac{V_a}{a} = \frac{V_c}{c} = \frac{V_r}{r} = \omega_o = 2\pi n$ n = Rev. per unit time

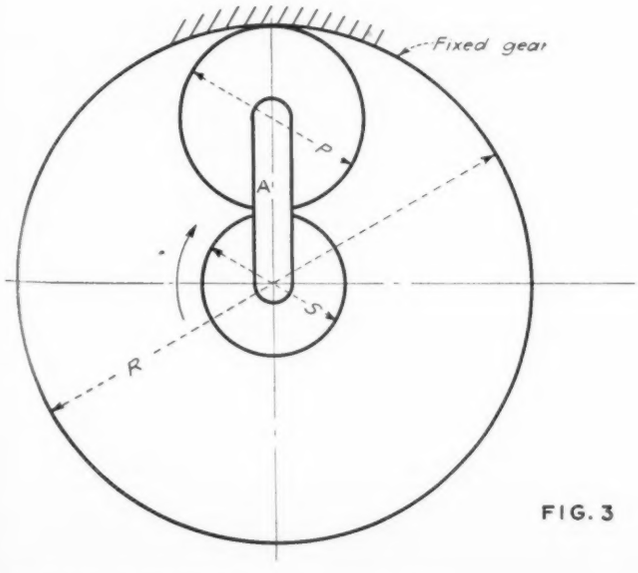
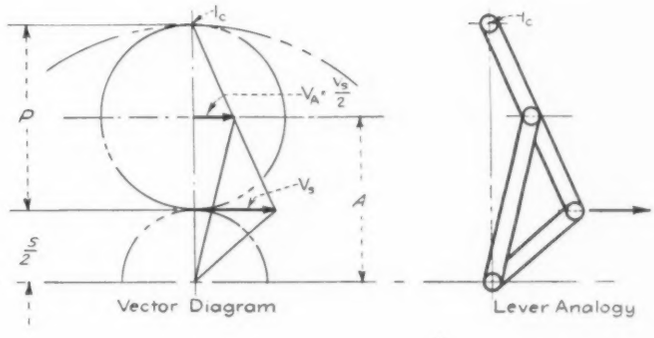


FIG. 3



Find rev. of A for n rev. of S

LET $\omega_s = 1$ $V_s = \omega_s \times \frac{S}{2} = \frac{S}{2}$ $V_A = \frac{V_s}{2} = \frac{S}{4}$

$\omega_A = \frac{V_A}{A} = \frac{S}{4A}$ or: rev. of A = rev. of S $\times \frac{S}{4A}$

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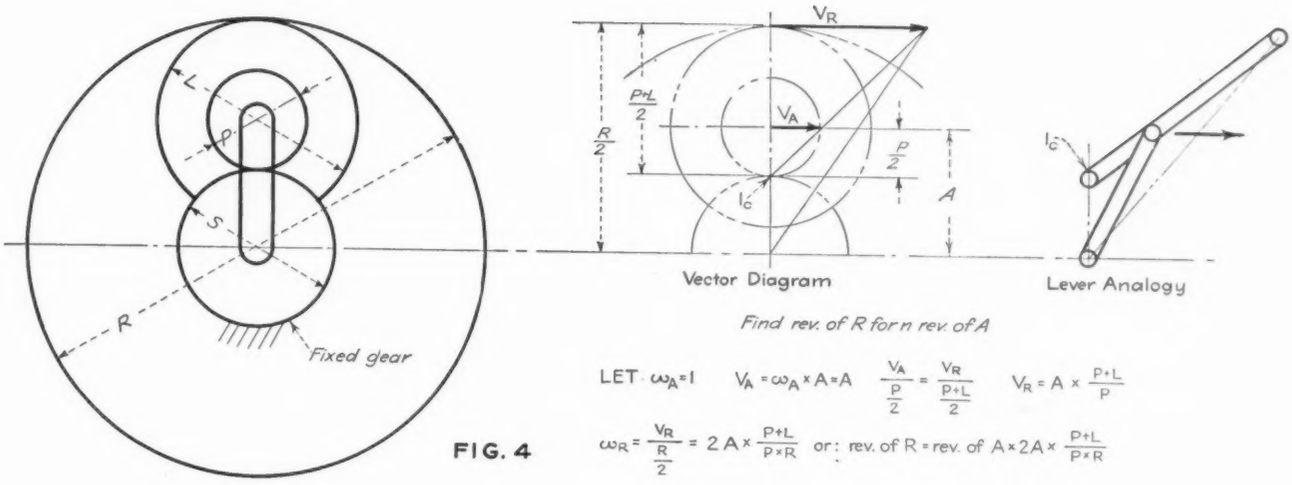


FIG. 4

Find rev. of R for n rev. of A

LET $\omega_A = 1$ $\quad V_A = \omega_A \times A = A$ $\quad \frac{V_A}{\frac{P}{2}} = \frac{V_R}{\frac{P+L}{2}}$ $\quad V_R = A \times \frac{P+L}{P}$

$$\omega_R = \frac{V_R}{\frac{R}{2}} = 2A \times \frac{P+L}{P \times R} \quad \text{or: rev. of } R = \text{rev. of } A \times 2A \times \frac{P+L}{P \times R}$$

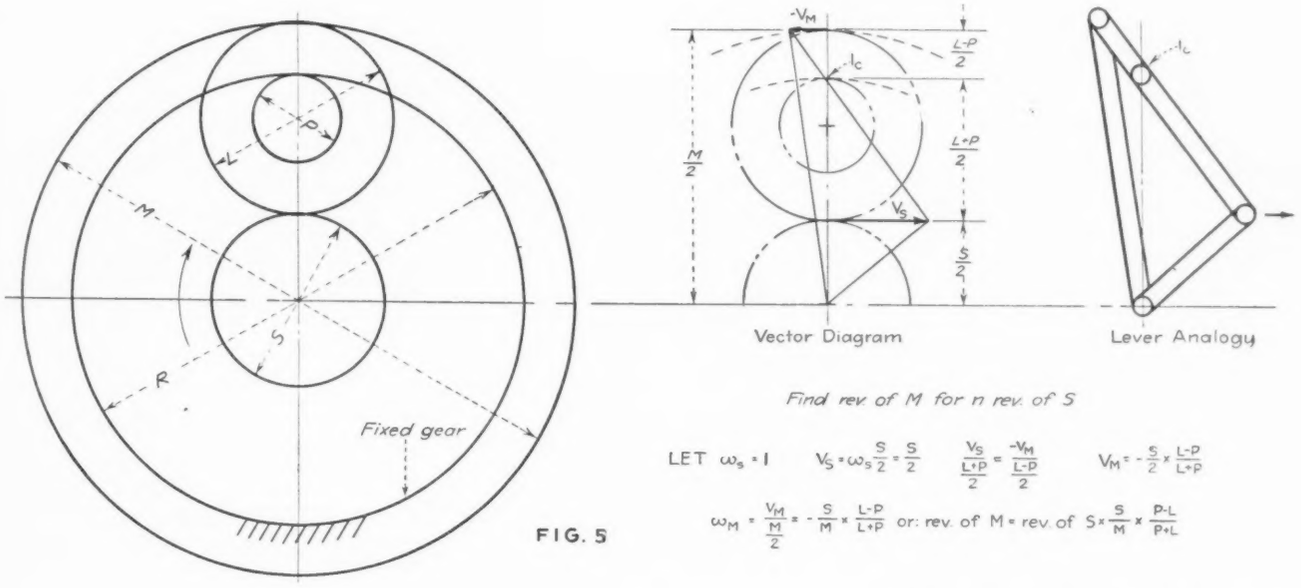


FIG. 5

Find rev. of M for n rev. of S

LET $\omega_S = 1$ $\quad V_S = \omega_S \frac{S}{2} = \frac{S}{2}$ $\quad \frac{V_S}{\frac{L+P}{2}} = \frac{-V_M}{\frac{L-P}{2}}$ $\quad V_M = -\frac{S}{2} \times \frac{L-P}{L+P}$

$$\omega_M = \frac{V_M}{\frac{M}{2}} = -\frac{S}{M} \times \frac{L-P}{L+P} \quad \text{or: rev. of } M = \text{rev. of } S \times \frac{S}{M} \times \frac{P-L}{P+L}$$

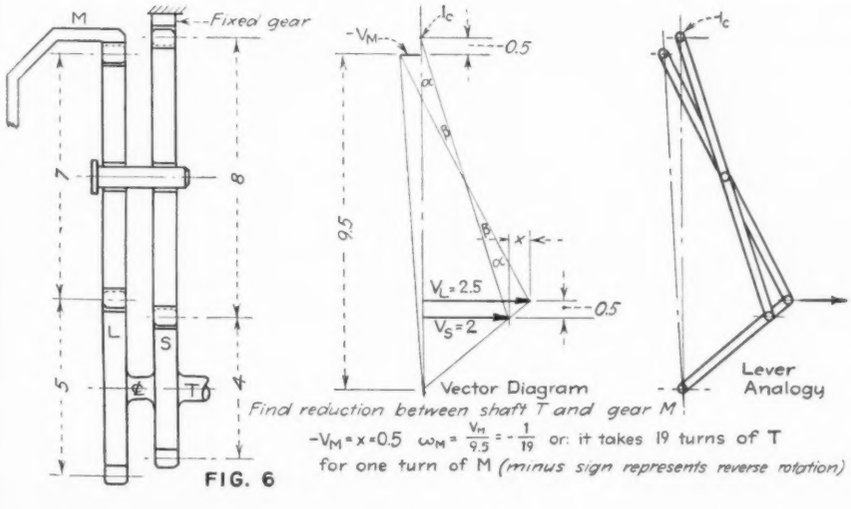


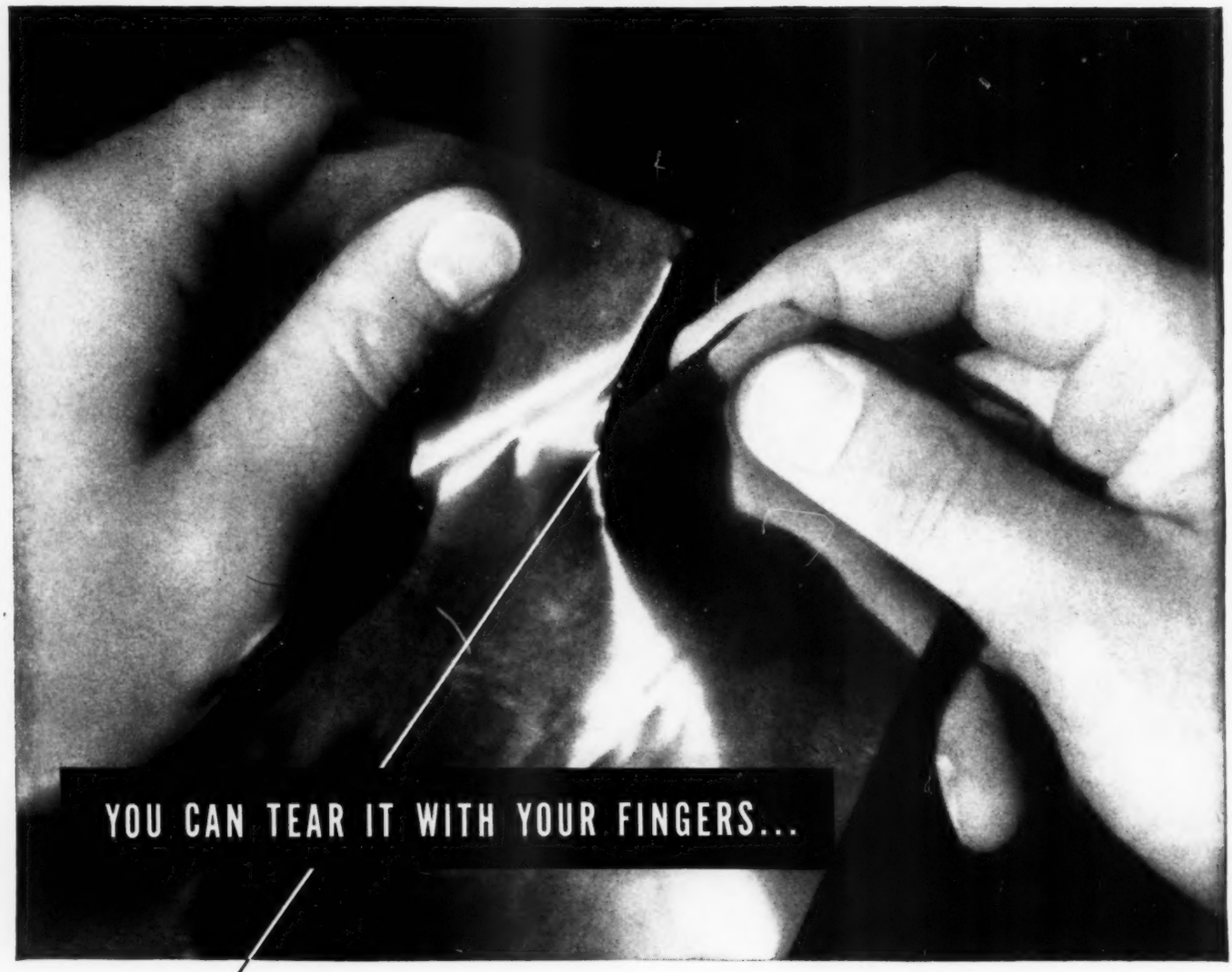
FIG. 6

Find reduction between shaft T and gear M

$-V_M = x \times 0.5$ $\quad \omega_M = \frac{V_M}{9.5} = -\frac{1}{19}$ or: it takes 19 turns of T for one turn of M *(minus sign represents reverse rotation)*

neous centers, and the levers are allowed to stretch while moving the driving lever through a small angular displacement, the points will assume a position that gives a picture analogous to the vector diagrams.

When analyzing epicyclic gear trains that are different from the types illustrated, the following steps should be taken. First, the instantaneous center, which is always on the fixed gear, is established. Next, a free-hand sketch of the vector diagram should be drawn. From this sketch, the mathematical calculations can be made. The number of teeth on each gear may be used in place of the pitch diameter if all gears in the train have the same diametral pitch.



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NEW MATERIALS AND PARTS

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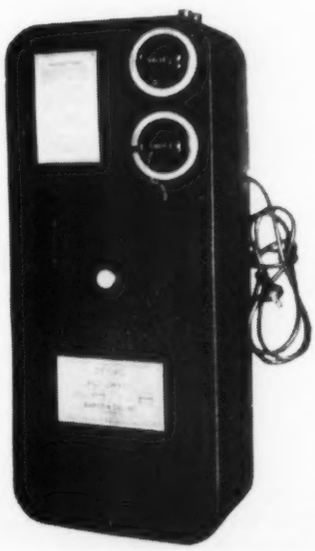
Automatic Gas Purifier

Baker & Co. Inc., Newark 5, N. J.



Installed at any convenient point on the low pressure line, the Deoxo Puridrier purifies such gases as hydrogen, nitrogen, argon, neon and saturated hydrocarbons, so that less than one part in a million of oxygen impurities remains, and then dries the gas to a dew point of better than —50 deg. Fahrenheit. When reactivating, the lower knob starts the timing circle, heats the drying chamber and allows a small flow of gas to pass through the drier The small gas stream becomes saturated with moisture before passing through a newly-developed Deoxo Converter, which combines the purging gas with the water vapor so that only water will be expelled to the atmosphere. When the unit is again ready for use, the green light glows. The catalyst used in the purification phase never requires reactivation. It should last indefinitely unless poisoned by sulphur compounds, carbon monoxide or some organic solvent vapor.

Packless Valve

The Henry Valve Co., 3260 W. Grand Ave., Chicago 51, Ill.

This push-button valve, with a forged brass body is suitable for handling oil, water, or any substance not corrosive to brass. The valve is normally open and is designed for operations where either manual or automatic instantaneous valve operation is desired, and where leakage around conventional packing would be objectionable. The valve has a removable disk and diaphragm, and with the threaded collar around the push-button, it can be mounted through a flush panel opening. For use with pressures up to 100 lb. per sq. in. this valve comes in sizes from ¼ through ½ inch.

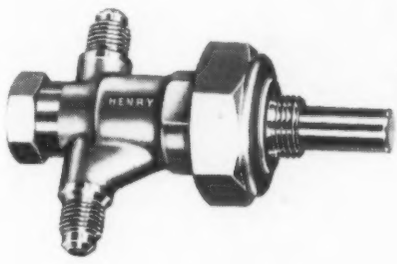
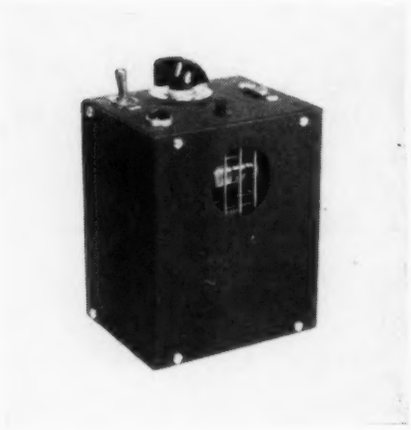


Photo-Electric Actuator

Globe Industries Inc., 125 Sunrise Pl., Dayton 7, Ohio.

Originally designed for use in photographic work this actuator circuit consists of a photoelectric tube, a miniature amplifier tube and a sensitive relay. A control is also provided so that adjustment can be made for ambient light. When the relay closes, a voltage of 4½ volts, from 3 size C flashlight cells in series, is available at

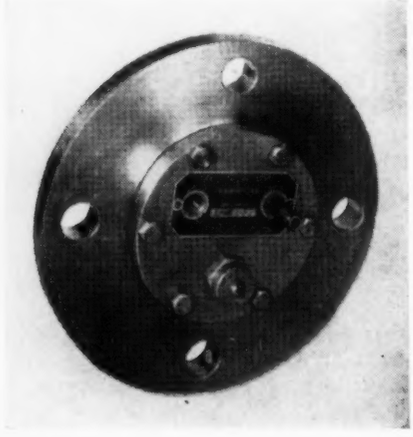


the outlet plug. The unit can be adjusted by the control so that the relay remains closed when the light intensity is increased momentarily, or can be made to follow an intermittent change of light up to about 5 cycles per second. The unit measures 3 x 4 x 5 in., and weighs about 3 lb. 2 ounces. Light sources are not included as part of the equipment.

Liquid Level Transmitter

Taylor Instrument Companies, Rochester 1, N. Y.

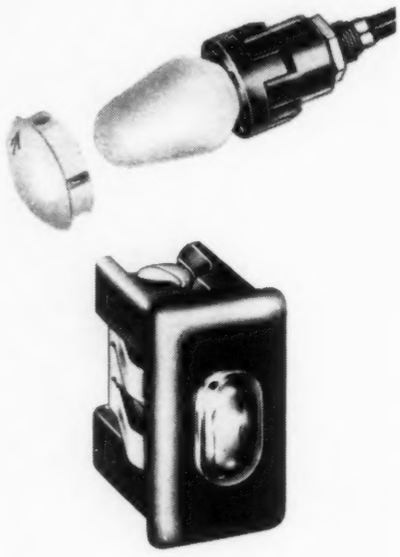
A single compact unit, the Taylor 229RF Liquid Level Transmitter, measures the level of the liquid and transmits an air pressure proportional to this level to the remotely located instrument. This transmitter measures the level of viscous liquids or liquids with solids in suspension; the level measurement of liquids or solutions which solidify in the usual pressure or manometer connections; and pressure measurement, up to 17 lb. per sq. in., of corrosive gases or liquids for which the diaphragm type element is particularly suited. The unit is made up of a metal diaphragm in a 3 inch 150 lb. per sq. in. stainless steel flange that can be attached to the bottom or the side of an open or vented tank. This transmitter operates on the force-balance principle. Being a 1 to 1 transmitter, the output air pressure is equal to the applied pressure or liquid head and has a range of 450 in. of water with an accuracy plus or minus one inch of water.



Pilot Lights

Hart Mfg. Co., 110 Bartholomew Ave., Hartford, Conn.

The upper lamp, see cut, uses a screw-base Mazda C-7 bulb in a plastic socket designed to prevent loosening of the bulb. This socket is mounted in a single 3/8 in. hole and is furnished with 6 in. pigtail leads. A translucent white plastic front panel lens is held

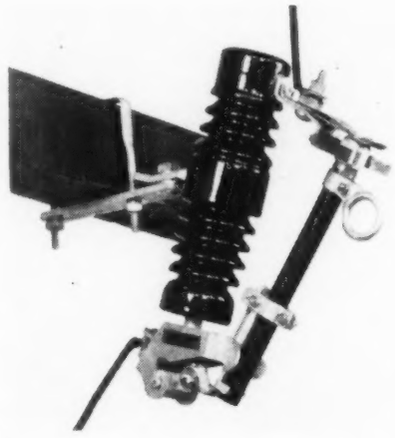


in position by a spring clip and mounts in a one inch hole. The other is a red or clear neon pilot designed to match Hart Diamond-H snap switches and convenience outlets. This pilot is spring mounted and requires no screws. It fits in an opening 5/8 x 1 1/4 in. and has a depth of one inch. The frame is made in various colors of plastic.

Fuse Cutouts

General Electric Co., Schenectady 5, N. Y.

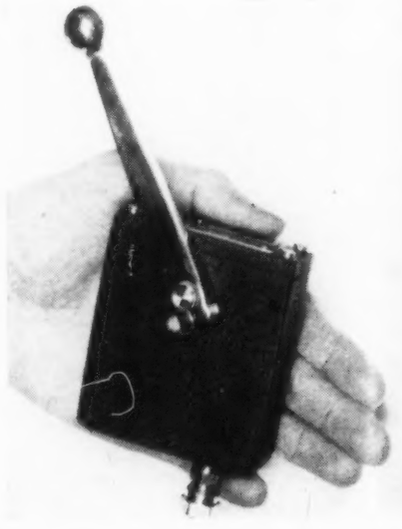
For use on distribution circuits of 15,000 volts and below, these open-type fuse cutouts, with drop-out fuse holder, have overcurrent protection throughout the full range of fault currents up to the rate of 2,000 amp. interrupting capacity. The ability of these cutouts to meet mechanical and electrical shock in stresses in service has been demonstrated by extensive tests. These cutouts can be fused with either conventional or Hi-surge fuse links. Mounting hangers provide for vertical, angle-tilted, and swivel positions of the cutout, and for combination crossarm mounting of the cutout with standard distribution lighting arresters. This design is available in three voltage ratings: 5,000, 7,500/12,500 GR Y, and 15,000 volts, and a rating of 100 amperes.



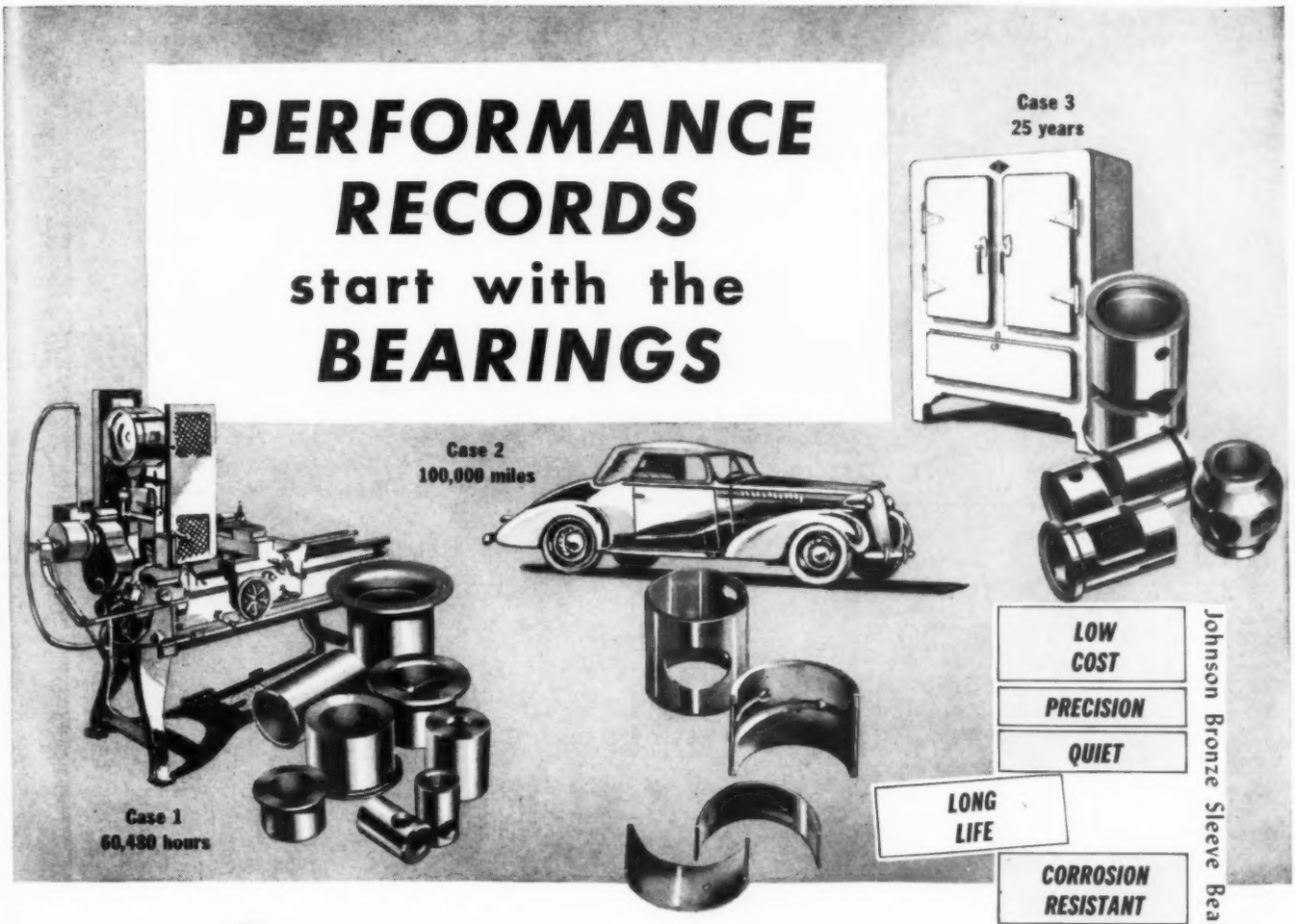
Hydraulic Remote Control

Sperry Products Inc., 15 St. & Willow Ave., Hoboken, N. J.

This miniature hydraulic remote control consists of two units, a transmitter and a receiver, which form a self-contained completely inclosed, hydraulic system when joined together by a single line of tubing and filled with oil. The transmitter and the receiver are exactly alike and any motion given to the arm of one will produce an equivalent motion on the arm of the other. The arms will move through an arc of 60 deg. and the receiver arm may be drilled at any location to obtain



PERFORMANCE RECORDS start with the BEARINGS



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LOW COEFFICIENT OF FRICTION
EASY TO INSTALL
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Johnson Bronze Sleeve Bearings Give You Every Worthwhile Advantage

BUYERS of all types of equipment are becoming more particular. Besides checking the price, they're asking . . . "How long will it run . . . at top efficiency . . . at lowest operating cost?" Performance records are becoming a major sales factor.

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Johnson Sleeve Type Bearings have achieved an enviable reputation for long life and economical operation. Our up-to-date methods . . . our skilled help . . . and more than forty years of exclusive bearing experience . . . . enable us to help manufacturers create new performance records. We help you decide which types of bearings will best serve your needs . . . we will produce them exactly to your specifications . . . and we can deliver them *on time*. Why not call us in NOW?

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Case 1

A prominent user of machine tools reports that the Johnson Sleeve Bearings installed in one of his units in 1927 are still operating efficiently after 60,480 hours of service.

Case 2

A traveling salesman tells us of the Sleeve Bearings installed in his car . . . 1937 model. After over 100,000 miles they are still delivering economical performance.

Case 3

A refrigerator owner reports that in a recent overhaul he checked the bearings. After twenty-five years of continuous service the Johnson Bronze Sleeve Bearings show no signs of wear.

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GASOLINE ENGINES

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The ever-increasing *preference* of users and dealers for equipment powered by engines bearing this world-famous trade mark, is a tribute to the record for *dependable operation* made by *more than 3 million* Briggs & Stratton 4-cycle air-cooled engines. Because they incorporate the constant engineering advancements . . . improved methods of precision manufacture . . . technical knowledge and experience of over 27 years of *continuous production*—today's Briggs & Stratton engines have no equal in value and performance.

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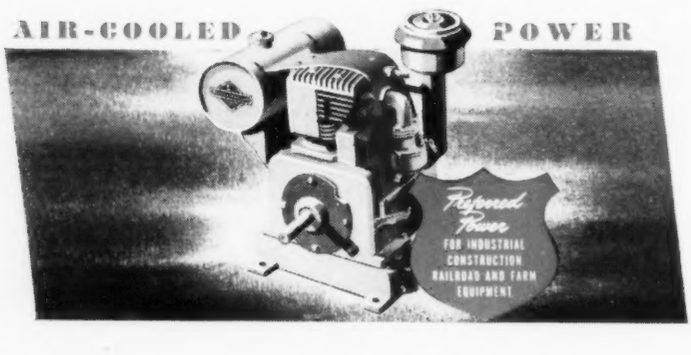
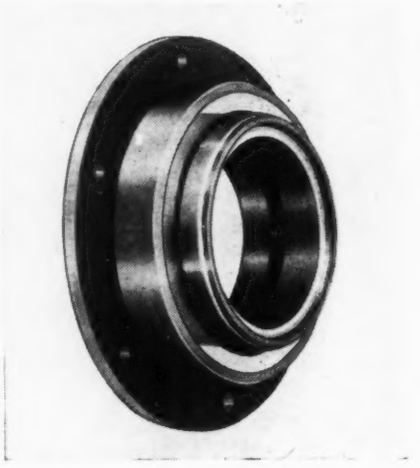


the desired linear travel of the actuated rod. With a torque capacity of 50 lb.—in. these units give remote control at distances up to 35 feet. The entire system is dust- and water-proof.

Carbon Ring Oilseal

Gits Brothers Mfg. Co., 1846 S. Kilbourn Ave., Chicago, Ill.

These carbon rings, which have been developed especially for shaft seal use, have a low coefficient of friction and self lubricating qualities that make them superior to high-lead bearing bronze in those applications where lubrication is poor or where shaft revolutions and resulting rubbing speeds are high. These carbon seals are heat-resistant, not



subject to warping, chemically inert and corrosion resisting. The entire assembly, known as the Gits DMC and DPC High Speed Carbon Faced Seals, seals against leakage of liquids or gases under pressure or vacuum by means of a radial seal joint made by positive contact between a stationary lapped seal surface built into the seal unit and a rotating lapped seal surface. It is stated that these seals can be applied to both horizontal and vertical shaft applications.

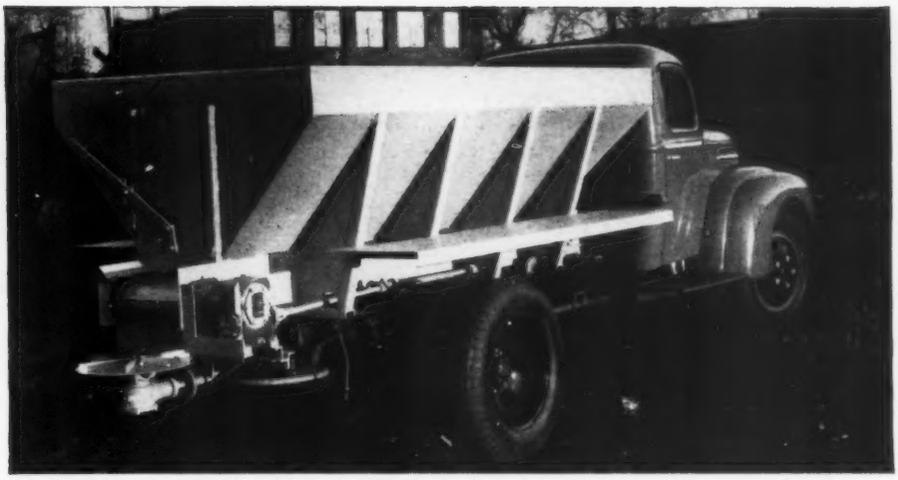
Inorganic Plastic Material

Rostone Corp., 105 S. Earl Ave., Lafayette, Ind.

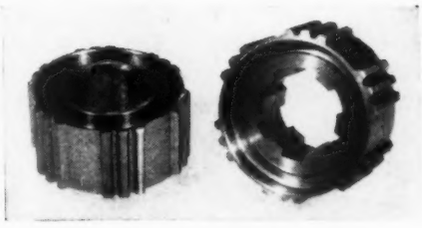
Chemically, Rosite is a form of calcium aluminosilicate with a microcrystalline grain structure integrally reinforced with asbestos fiber. Physically, this synthetic stone possesses many of the desirable characteristics inherent in a stonelike material: It is uneffected by oil, sunlight, alkali, age and temperatures up to 900 deg. Fahrenheit. Its compressive strength ranges from 12,000 to 15,000 lb. per sq. in. with a modulus of rupture of 5,000 to 7,500 lb. per sq. in. depending on the particular formulation used. Available in a number of colors, it weighs ap-

GEAR HIGHLIGHTS

VOL. XI NO. 4

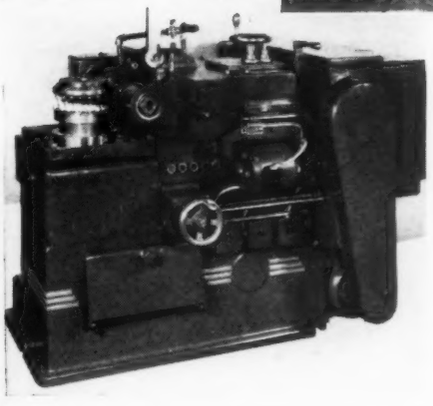


Conveyorized lime spreader operated through standard reducer *(See NEW WESTON CONE-DRIVE LIME SPREADER, p. 2 of GEAR HIGHLIGHTS).*



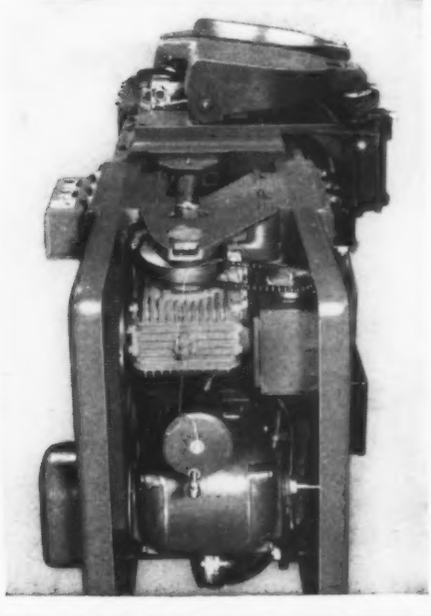
A single machine finish cuts transmission shifter clutch hubs at Ford at two every 55 seconds. *(See "SHEAR-SPEED," page 2 of GEAR HIGHLIGHTS).*

Precision cutting eliminates need for lapping Cone-Drives. *(See PRODUCING CONE-DRIVES on page 3 of GEAR HIGHLIGHTS).*



Below: "New" gears save space, increase acceleration and deceleration rate without high inertia loads. *(See FLASH-WELDER PROBLEMS SOLVED, page 2 of GEAR HIGHLIGHTS).*

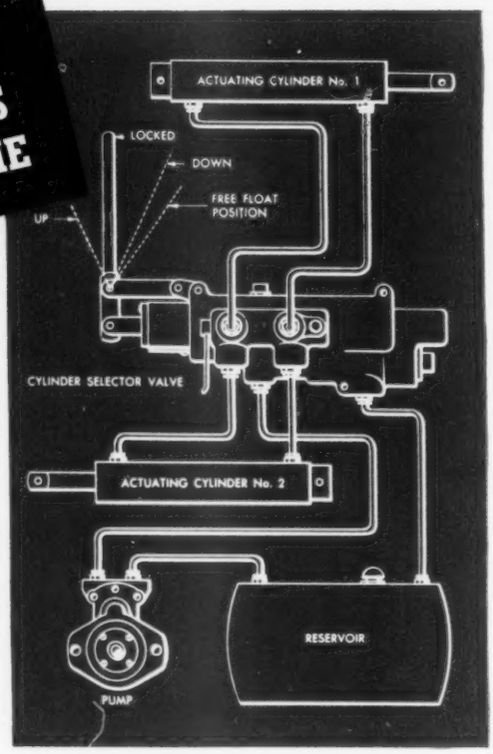
We will be glad to send you the current issue of GEAR HIGHLIGHTS VOL. XI, NO. 4 giving the complete story on the above developments.



MICHIGAN TOOL COMPANY 7171 East McNichols Road DETROIT 12, -- U.S.A.

ADEL *Hydraulic Equipment*

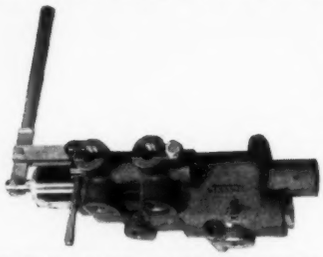
HOW TO DO TWO THINGS AT ONE TIME



Here's a blue print for doing *two* operations at once. A simple hydraulic system, consisting of a reservoir, pump, valve and two actuating cylinders.

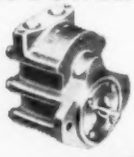
A special feature of this system is the new Adel Open Center Selector Valve. It controls both actuating cylinders, simultaneously or individually. Loads may be hydraulically locked in any position, or be set for free movement. It affords high speed operation, for lifting or lowering.

OPEN CENTER 4-WAY SELECTOR VALVE—Built-in rotating selector valve permits individual control of two actuating cylinders. The main slide valve has four positions: *up, locked, down* and *free floating*. The handle is "spring-loaded" and automatically returns to the *locked* position. A detent holds the handle in the *free floating* position. Internal relief valve is preset for specific application requirements. Maximum operating pressure, 1000 psi.



HYDRAULIC ACTUATING CYLINDER—Double acting type. Rugged construction; withstands high loads. Seals are easily and quickly replaced. Special brass scraper ring cleans foreign matter from piston rod; protects the system.

HYDRAULIC POWER PUMP—A new, gear-type hydraulic pump. At 2250 rpm, this compact unit delivers 12.5 gpm at 800 psi. May be direct-connected to motor, or belt driven.



Adel stands ready to work with you on any problem in the field of hydraulics. At your service are Adel's years of experience, extensive manufacturing facilities and practical engineering skill. Address Adel Precision Products Corp., 10757 Van Owen Street, Burbank, Calif.

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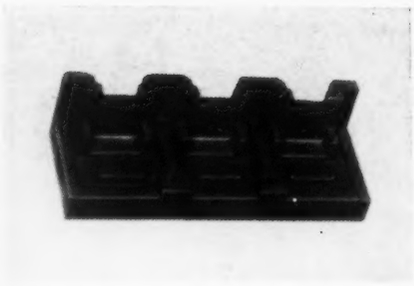
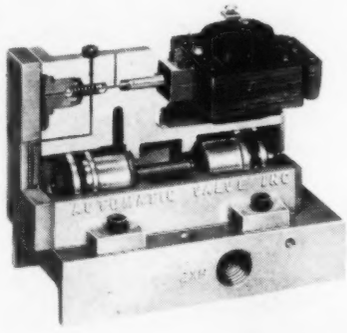


proximately 0.058 lb. per cu. inch. There is no cold flow and no distortion of age, and this material is being molded in intricate shapes to close tolerances. When threaded connections are desired, anchored metal inserts can be provided, or the material itself may be drilled and tapped.

Solenoid Valves

Automatic Valve Inc., 37415 Grand River, Farmington, Mich.

Normally open or closed, the Model SV-3, 3-way, 3 port solenoid operated air valve, is used for controlling single action air cylinders. There is no metal-to-metal contact because O-ring type



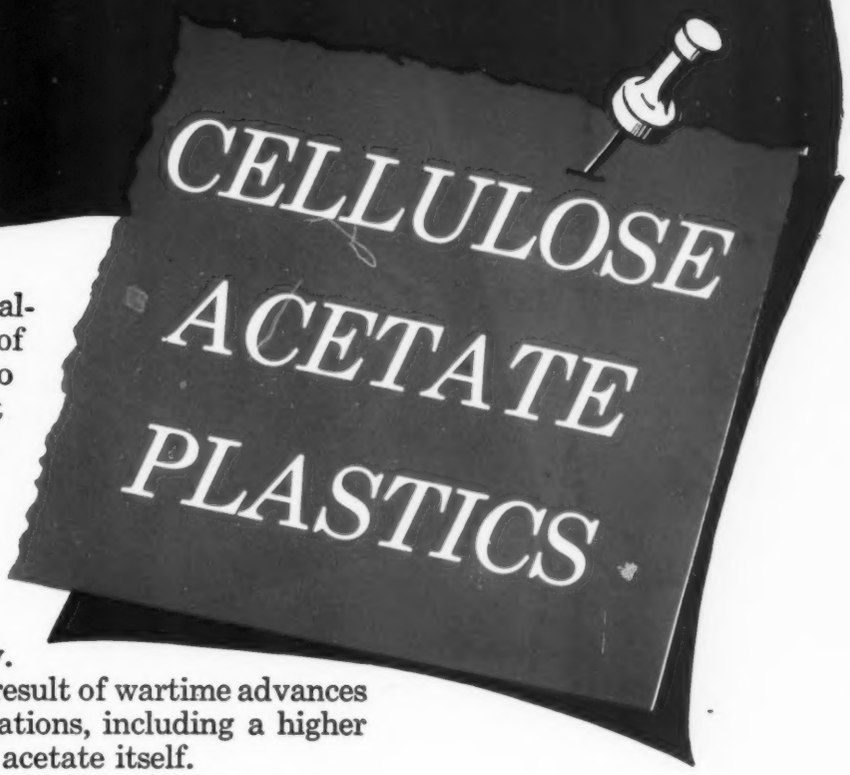
seals are used, and the valve can be mounted in any position. The valve is a balanced piston type, valve-pressure sealed. It comes in sizes ¼, ⅜, ½ and ¾ in., to operate on pressures from 5 to 150 lb. per sq. inch. Power required to operate the valve is 1.42 amp. at rush-in and 0.22 amp. when sealed, from 110 volt, 60 cycle lines.

Radiation Detector

North American Philips Co. Inc., 100 E. 42 St., New York, N. Y.

This instrument is battery powered to adapt it for field or laboratory survey work. The Geiger tube is inclosed in a housing that permits differential detection of hard and soft radiation components and is connected by flexible cord to the internal circuits. The indicating meter shows the rate at which radioactive pulses are received and also is used to determine the potential applied to the Geiger-counter tube. Visual

A better buy than ever before!



CELLULOSE acetate has always been the standby of molders and designers who want reliable performance at low cost, when the job calls for thermoplastics.

Today, acetate offers outstanding resistance to heat or moisture, giving finished products much greater dimensional stability. This basic advantage is the result of wartime advances in improved acetate formulations, including a higher degree of acetylation in the acetate itself.

The properties that have kept cellulose acetate at the top—its durability, toughness, absence of odor, and its unsurpassed workability, to name but a few —are now reinforced by this increased dimensional strength. More and more molders are finding *it's the best buy in the plastics market!*

Hercules does not make cellulosic plastics or molding powder, but supplies the high-quality cellulose derivatives from which they are made. Write for technical details on these base materials.

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Greatly improved dimensional stability and durability

Crystal-clear or colorful

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Odorless and tasteless

Unsurpassed workability with minimum waste

Save and Sell with
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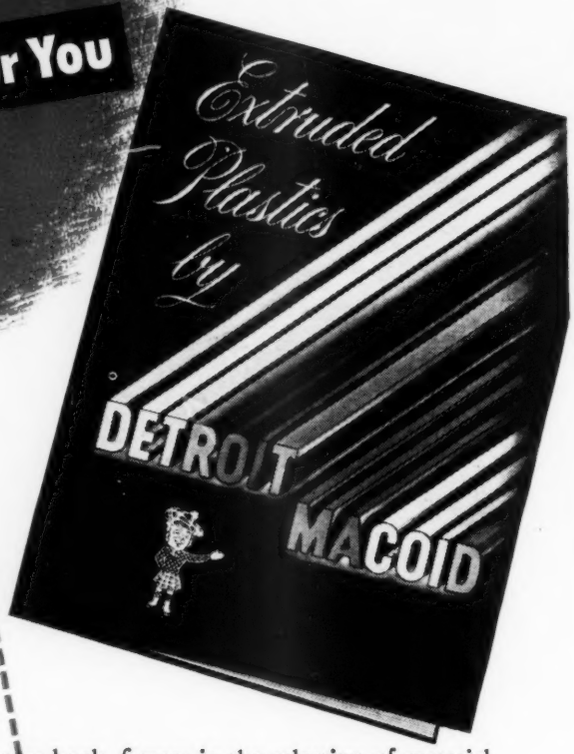
CP7-9

The Facts
Are Here For You



In this Book:

You will find in this new book, factors in the selection of material, tool making, the how and why of extrusion, uses for extruded plastics, the how and why of injection moldings, and characteristics of plastics. It includes a brief history of plastics and a library of more than 270 stock extrusions.

Here also are quick answers to your questions on the properties of the following: cellulose acetate, cellulose acetate butyrate, ethyl cellulose, methyl methacrylate, nylon, polythylene, polystyrene, polyvinyl chloride, and viny-chloride-acetate.

In content as well as in physical form, this book makes a beautiful addition to any library. The book is case bound, liberally illustrated, and will be sent without charge or obligation to persons who request it on their business letterheads. Act quickly, as the supply is limited.

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Originators of Dry Process Plastics Extrusion

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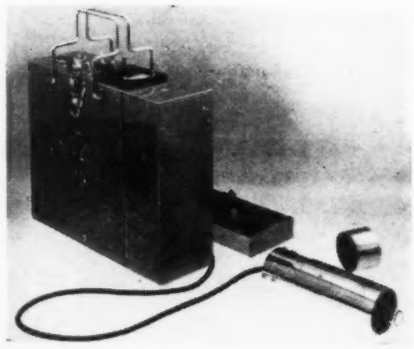
EXTRUSION AND INJECTION MOLDING

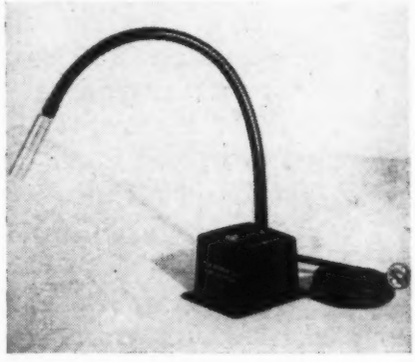


indication of the pulse rate is provided by the flasher that is panel mounted. Audible signals can be had by connecting head phones to the jack terminals. The complete instrument, with batteries, weighs 17 pounds.

Adjustable Spotlight

The Benton Co., 351 S. LaBrea Ave., Los Angeles 36, Cal.

The Opti-Spot, a small self-contained spotlight, operates on 110 volts a.c., voltage being reduced by a transformer. The light cell contains a focusing condenser lens that regulates the size of the spot. The bulb is an ordinary 6



volt automotive type, with a beam sufficiently strong to permit use of the lamp at any distance up to 6 ft. from the work. Two models of Opti-Spot are available: Model A has a 16 in. flexible tubing connection between lamp and base, Model B has an 18 in. rubber covered cord between lamp and base.

Diamond Lapping Compounds

Industrial Processing Div., Dept. PE—1, The Magnus Chemica Co., Inc., Garwood, N. J.

Precision graded diamond grits, supplied in eight particle sizes from approximately 120 microns, for coarse cutting, to approximately 1 micron, for high finishing, are available in two forms. One is the stick form with the consistency of lipstick; the other is the paste form in a collapsible tube. A case hardened steel roller for applying and spreading the compound is supplied with each tube or stick. Each

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Specify Federal Ball Bearings for the heavy loads—in any range or size. Write for catalog "K."

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Whatever you make, chances are there's a Unichrome Coating that's *exactly right* for your product—for service requirements, for eye-appeal. It will pay you to look it up. Write us today on the properties you need in a coating, and we'll send you full information. No obligation, of course.

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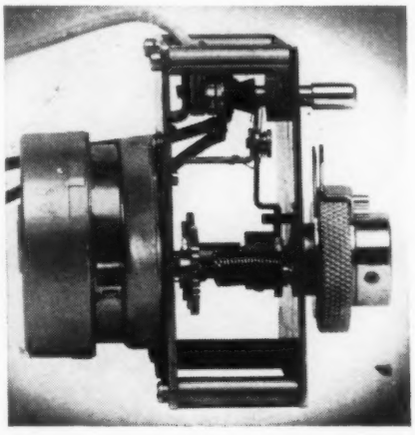
grit size is identified by an individual color in the compound itself. The sequence of finishing stages can be exactly specified by color and grit size. The color of the hardened steel roller, the tube and the compound are the same for each grit size.

Industrial Reset Timer

American Time Corp., Springfield 1, Mass.

Designed to be permanently installed on a panel, this unit comes in time cycle ranges of 15, 30 and 60 sec., 5, 15 and 30 minutes. The timer is made of two mounting plates, a reset synchronous motor, a torsion spring to return motor to original position and a motor actuated indicator. Known as the P 147-60 Panel Mounted Reset Timer, the unit weighs approximately 1 lb. and measures 3x3x2½ in. The device or devices controlled by the reset timer are connected in parallel with a synchronous motor and will operate as long as the motor is energized. When the time cycle is complete, the unit resets automatically. This timer operates on 110 volts, 60 cycles a.c. with a 1,500 watt capacity. A portable version, Model P 134-60, for use where the timing element can be separate from the product, is also available in the same ranges.



Keying Relay

Signal Engineering & Mfg. Co., 164 W. 14 St., New York, N. Y.

Having a core of Armco iron, fully annealed after machining, to minimize residual magnetic effects, this relay is available with several types of contact arrangements: Normally open, closed, or transfer contacts, in various combinations. The coil winding is sealed in cellulose-acetate to provide dependable service under unfavorable humidity conditions. The frame is rectangular in form, providing a box-like rigidity that insures freedom from distortion under shock and vibration. The electrical con-

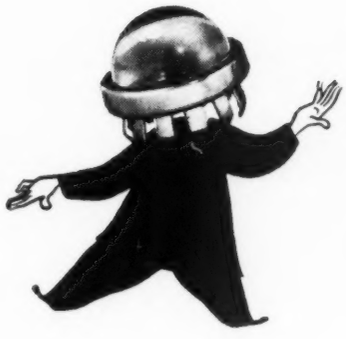
Have you an opening for a bright, young PLUG BUTTON?

"I'm Mr. PLUG BUTTON! The United-Carr people designed me as a simple cover for holes drilled, punched or moulded in metal—or Plastics. Since then I've fathered quite a family. Like me, all of them snap into place by hand, hold tight by expanding spring action—yet are easily removed and replaced whenever you wish. Like me, too, they save you money—inexpensive, they cut costs, speed production, make a finer finished product.

I'm mighty proud of these sons. Some have holes punched in their caps—they make excellent vent plugs. Others of various shapes and sizes fit special applications. My newest offspring have Plastic windows of different sizes, shapes and colors set into them. They really star as signal or indicator lights.

They're a footloose lot—these boys of mine. Already they've gotten round quite a bit in many industries. But I'm certain there are a lot more openings they can fill . . . a lot more places they can save smart manufacturers money and speed their production. Look over your products critically—then drop us a line. If we haven't just what you need, United-Carr's engineers will be glad to design the PLUG BUTTON you need."

P.S. I've had my family album printed up recently, complete with pictures of most of the boys and their vital statistics.
Send for your copy today! ➡ ➡ ➡



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DEPT. P-1, CAMBRIDGE 42, MASSACHUSETTS

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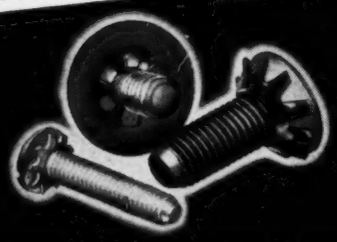
See SCOVILL!

FOR SEMS WASHER SCREW ASSEMBLIES

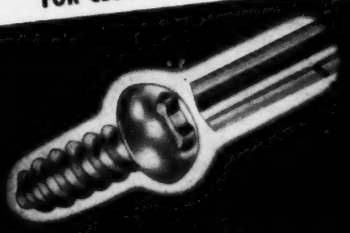


Washer permanently fastened on, yet free to rotate. Easier, faster driving. No fumbled, lost or forgotten washers. Matching finish on both parts. Easier ordering and balanced inventories.

FOR PHILLIPS RECESSED HEAD SCREWS

Increase assembly speed up to 50%! Cut down injuries to workers with no burrs, no skids. Reduce production costs. Reduce rejects! Improve product appearance! Go modern with Phillips!

FOR CLUTCH-HEAD SCREWS



The latest type recessed-head screw. Screw locks on driver. Can't fall off. No screw-driver slippage. Easy to assemble. Exceptional driver life. Ordinary screw-driver may also be used.

FOR SPECIAL COLD-FORGED FASTENINGS

Scovill is expert in cold-forging unusual special fastenings, such as the one shown. Scovill designing ability, engineering skill, men and machines save money for customers. Consult Scovill!

Look at the fastenings you're now using—and see if they're the best for the job. Get better results—at less cost—with modern fastenings. If you use fastenings in *large quantities,* it will pay you to find out what Scovill can do for you. Fill out and mail the coupon below—*now!*

MAIL COUPON TODAY!

Scovill

QUALITY FASTENERS FOR QUANTITY CUSTOMERS

SCOVILL MANUFACTURING COMPANY
WATERVILLE SCREW PRODUCTS DIVISION
WATERVILLE 48, CONN. (PE-8)

Please supply more information on:

- ☐ Scovill SEMS Washer Screw Assemblies
- ☐ Scovill PHILLIPS Recessed Head Screws
- ☐ Scovill CLUTCH HEAD Screws
- ☐ Scovill Special Cold-forged Fastenings

NAME_____

COMPANY_____

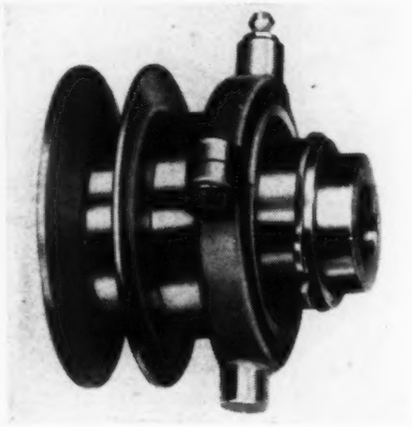
ADDRESS_____

tacts are designed to carry 5 amp. at 115 volts a.c., and the relays can be supplied in hermetically sealed cans. A model with a 5,000 ohm coil will respond to 20 pulses per sec. on a 5 milliamp. coil current when connected to 90 volts d.c. through a series resistor.

Friction Clutch

V-Belt Co., 3757 Wilshire Blvd., Los Angeles 5, Cal.

Designed to grip or release directly on V-belts, the "Ball-lok" friction drive clutch units can be used either as driving or driven pulleys. In operation, smooth clutching action is the grip of the sidewalls of the pulley against the

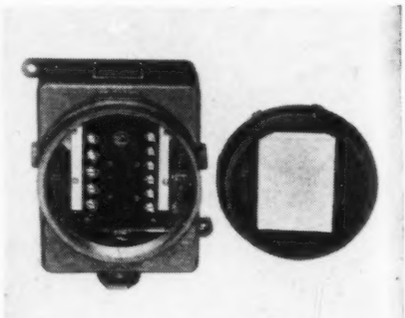


belt. When the clutch is open, the belt slackens and idles on a free-running, grease sealed, ball bearing with no belt drag or creep. A stop ring prevents over-travel of the cam sleeve when disengaging. The cam sleeve has a projected flange on which a shift collar is mounted. The clutch is available in four sizes having 3¼ to 5 in. sheave diameters, and are 2 15/16 to 3 1/16 in. in overall length.

Liquid Level Control

Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.

The level control, Type 10CD1X, has been designed for general application with emphasis on the chemical processing field. Contact with the liquid is made only by stainless steel probe rods; no floats or other moving parts are



AN IMPORTANT ANNOUNCEMENT

TO INTRODUCE

Lustrex

MONSANTO'S NEW HEAT-RESISTANT POLYSTYRENE

Ready now for applications formerly outside of polystyrene's practical limits is Monsanto's Lustrex. A radically improved product, this new polystyrene adds high heat resistance, quick setting characteristics, and increased strength to the already outstanding qualities of popular Lustron.

Consider all these advantages which Lustrex has over ordinary polystyrene . . . see if they don't offer you new opportunities in today's competitive markets:

1. **HIGH HEAT RESISTANCE**—Lustrex has an ASTM distortion point 10-30 degrees Fahrenheit higher than ordinary styrene molding compounds. Molded articles which will withstand scalding water for periods of ten to fifteen minutes without visible distortion have been produced from Lustrex.
2. **FASTER MOLDING CYCLES**—In some cases, molding cycles have been speeded as much as 30% without affecting appearance of the finished product.
3. **GREATER FLEXURAL STRENGTH**—Flexural strength of Lustrex has been increased to 12 to 14 thousand pounds per square inch.
4. **INCREASED RESISTANCE TO IMPACT**—Assures less breakage in finished molded articles.
5. **NO SPECIAL EQUIPMENT OR ALTERATIONS NECESSARY.**
6. **CHEMICALLY INACTIVE**—Unaffected by acids such as sulfuric, hydrochloric, hydrofluoric.
7. **AVAILABLE IN A WIDE VARIETY OF FAST COLORS.**
8. **APPEARANCE UNIMPAIRED.**
9. **DIMENSIONAL STABILITY EVEN UNDER STRINGENT CONDITIONS.**
10. **LOW WATER ABSORPTION.**

It will pay you to learn more about remarkable Lustrex. Get full technical data from: MONSANTO CHEMICAL COMPANY, Plastics Division, Springfield 2, Mass. Lustrex: Reg. U. S. Pat. Off.

IMPORTANT PHYSICAL QUALITIES OF LUSTREX

PROPERTY	LUSTREX
Molding quality	Excellent
Injection Mold. Temp. °F.	350-550
Injection Mold, Pressure, psi	10,000 and up
Specific Gravity	1.05
Flexural Strength, psi	12,000-14,000
Flexural Deflection, inches	0.15-0.25
Impact Strength, ft. lbs. per inch, (unnotched)	3.2-3.6
Heat Distortion Temp., °C. (air bath)	87-88
Dielectric Constant, 1 megacycle	2.5-2.7
Power Factor, 1 megacycle	0.0001-0.0005
Water Absorption, % (24 hrs.)	0.04-0.05

MONSANTO
CHEMICALS AND PLASTICS

SERVING INDUSTRY . . . WHICH SERVES MANKIND

"Zincilate*"

Cuts Corrosion Costs!

"Beats the Devil Out of Corrosion"

20 YEARS LIFE

Estimated Usage, Based on 1000 Hours ASTM Salt Spray Treatment

●ZINCILATE, THE ONE-COAT SELF-PROTECTING ANTI-CORROSIVE COATING, can be applied on ferrous metals and aluminum . . . sheet, strip, wire, forgings and castings. ZINCILATE can be sprayed, dipped or brushed. No special equipment is required. It can be baked either in convection or infrared oven or by hot air blast, or by open oxyacetylene flame. Accelerated tests to A.S.T.M. specifications show no corrosion of ZINCILATE after one thousand hours' exposure to salt corrosion treatments.

ZINCILATE IS NOT A COMMON, TYPICAL ZINC BASE PAINT

ZINCILATE is a revolutionary inorganic coating containing no resins, oils or solvents. It is based on chemical and physical principles never before employed in anti-corrosive coating materials. ZINCILATE is applied to a thickness of only two or three mils. Protection with ZINCILATE does not depend on the self-sacrificial action of zinc, therefore, does not depend on a heavy coating. ZINCILATE weighs one ounce per square foot at two mils thickness and covers four hundred square feet per gallon.

Zincilate is a low cost coating. It is a one-coat application, saving labor and material. It requires no primer. It has great covering power due to its uniform thickness in a coating film of two to three mils. It lasts many times as long as ordinary protective coatings, eliminating replacement and repair.

USES for "ZINCILATE"

Iron and Steel Manufacture

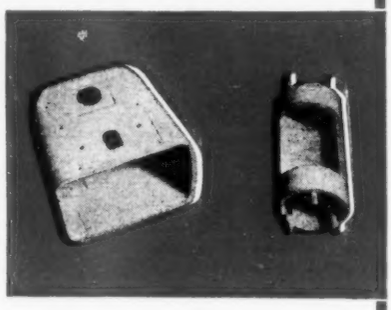
Shipbuilding

Railroads

Construction

Utilities

Manufactured Products



Characteristics and Technical Data: Color: gray. Finish: dull matte or bright polished. Viscosity: 20 seconds ± 4, #4 Ford cup initial; after five days, 35 seconds. Weight, gallon, 26.70 ± .5. Hardness: Rockwell at 5P measures 40B. Abrasion: excellent — 68,000 cycles Taber F10-1000 gm. load. Adhesion: excellent. Coverage: 400 square feet per gallon (approx.). Corrosion Resistance: salt spray treatment for 1,000 hours, no failure (estimated equivalent, 20 years in use). Weatherometer — 3,600 hours, no failure. Film Properties: withstands air temperatures to 700°F. transient heat to 6300°F.

*Trade Mark

INDUSTRIAL METAL PROTECTIVES, INC.

137 NORTH PERRY ST. **DAYTON 2, OHIO**

***PRICES:** $8.00 per gallon in drums • $10.00 per gallon in one-gallon cans • $9.50 in 5-gal. cans • Tank Car lots of 10,000 gal. $7.20 per gal. F.O.B. Newport News, Va.*

BUY "ZINCILATE" FOR YOUR anti-corrosion applications, *today!*

Use this convenient order form . . . we'll bill you upon shipment.

Ship _____ **gallons "Zincilate" @** _____ **per gallon to:**

Company _____

Address _____

City _____ **Zone** _____ **State** _____

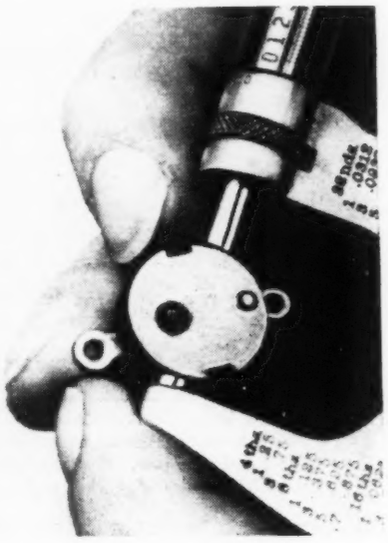
Signed: _____ **Title** _____

needed in a tank. Accuracy is independent of temperature and pressure. This unit is an alternating current control that combines a probe circuit and transformer to operate a direct current relay. Two probe rods, wired to the control, project into the tank to the levels corresponding to the low point where pumping is to start, and the high point at which pumping stops. It is available with explosion-proof housing, see cut, or pressed steel. The control operates from 115 to 230 volts, 25/60 cycles alternating current.

Snap Action Switch

Mu-Switch Corp. Inc., Canton, Mass.

A snap action precision switch, no bigger than a dime, is rugged and compact. It serves in the electrical circuits of dispensing machines, automatic cooking machines, airplane wing flashers

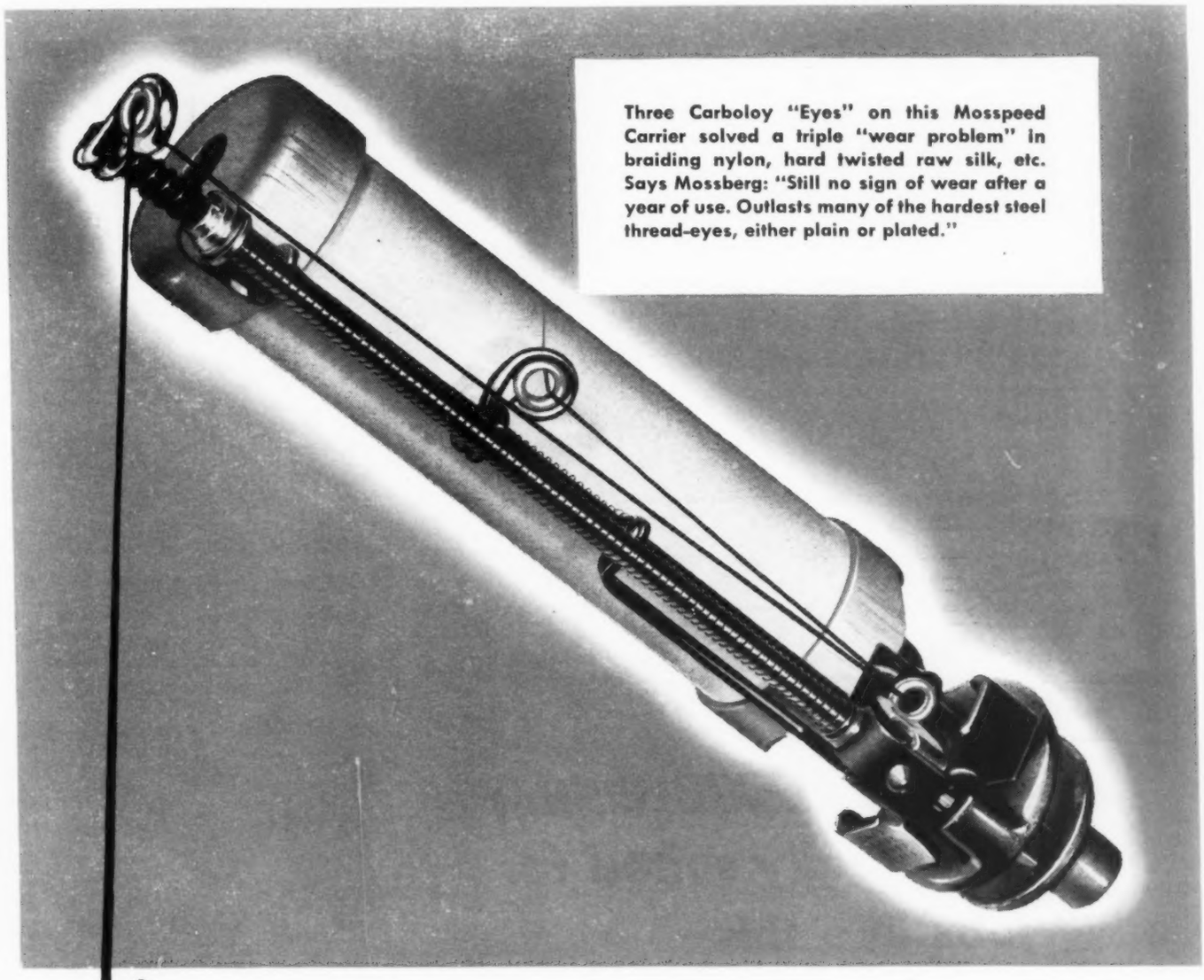


and other industrial electric circuits. The "Q-Switch" has a high current carrying capacity and a long life. This switch is available normally opened or normally closed, single— or double throw single pole.

Time Cycle Controller

The Bristol Co., Waterbury 91, Conn.

Known as the Model C500 Impulse-Sequence Cycle Controller, this instrument is used on processes where a number of factors, such as the opening and closing of valves, switches, dampers, retorts and presses, and the starting, stopping or reversing of motor driven pumps and blowers must be accurately timed according to a fixed program. In this controller, time measurement and pilot valve operation are handled by separate mechanisms. Separating these two functions gives accurate timing with high speed and torque for valve operation. Timing is accomplished by 2 Telechron-driven aluminum



Three Carboloy "Eyes" on this Mosspeed Carrier solved a triple "wear problem" in braiding nylon, hard twisted raw silk, etc. Says Mossberg: "Still no sign of wear after a year of use. Outlasts many of the hardest steel thread-eyes, either plain or plated."

You can "PULL THE WOOL" over These Eyes ... and They like It!

Threads—such as nylon or silk—may *seem* soft but they actually wear through even hard steel or porcelain rapidly! Ask the textile manufacturer! Fast wear on eyes or guides through which threads pass causes frequent downtime of machines and costly loss of production.

To stop that loss, manufacturers tried Carboloy Cemented Carbide Guides—and found they kept machines running as much as 100 times longer.

Thousands of Wear Resistant Uses!

This is but one of the thousands of wear resistant uses in which Carboloy hard metal today is helping make equipment last far longer and operate far better than ever before possible. A wide range of products—from fish rods to window screens—have benefited. Perhaps Carboloy can solve your wear problem too! Carboloy Company, Inc., 11105 E. 8 Mile Road, Detroit, Mich.

CARBOLOY®

Hard Metal

TO REDUCE WEAR ON MACHINES AND PRODUCT PARTS

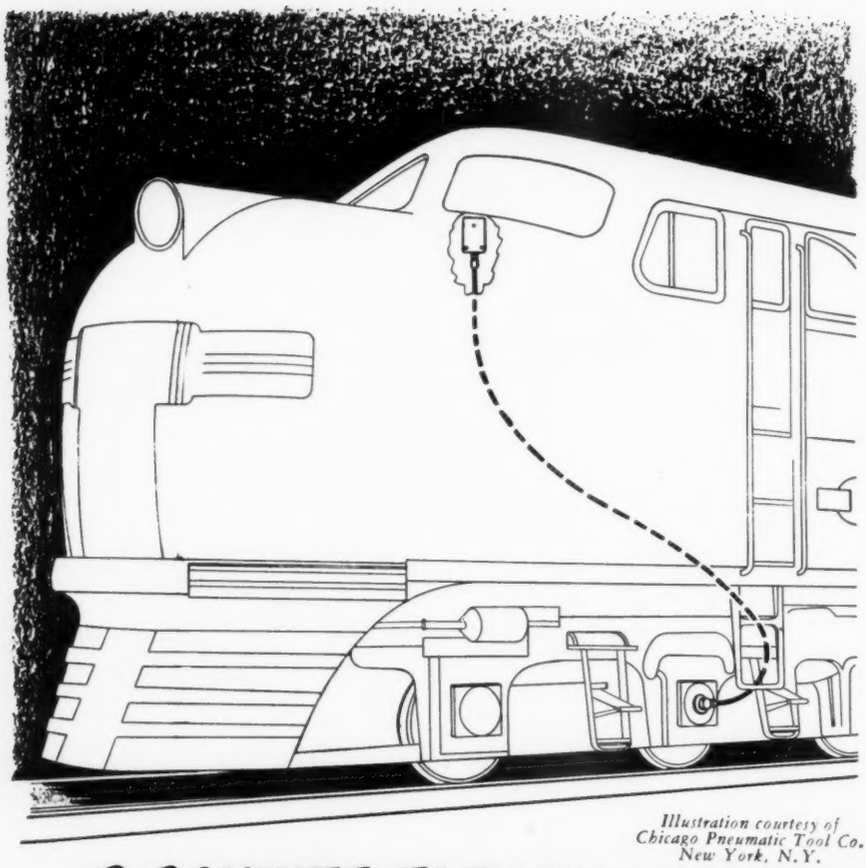


Illustration courtesy of Chicago Pneumatic Tool Co. New York, N.Y.

S.S.WHITE FLEXIBLE SHAFTS are ideally suited for jobs like this—

In the application illustrated above an S. S. White Flexible Shaft is used to operate a train speed indicator or recorder in the engineer's cab from a take-off on the journal box of one of the axles. It is ideally suited for the job for two reasons:

1. It is as simple a means as there is for accomplishing the drive—a single mechanical unit, easily installed from axle to instrument.

2. It performs dependably under the severe service conditions common to railway operations, which include extremes of weather, temperature, and climate and long periods of operation at high and varying speeds.

Where a simple, dependable means of transmitting rotary power is needed, it pays to consider S. S. White Flexible Shafts.

For full facts and engineering data about these shafts and how to apply them get a copy of this

260-PAGE FLEXIBLE SHAFT HANDBOOK

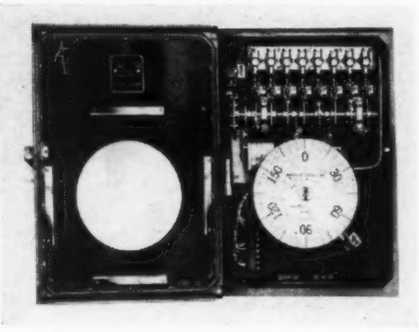
A free copy is yours if you write for it direct to us on your business letterhead and mention your position.

S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO. DEPT. D 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS • FLEXIBLE SHAFT TOOLS • AIRCRAFT ACCESSORIES
SMALL CUTTING AND GRINDING TOOLS • SPECIAL FORMULA RUBBERS
MOLDED RESISTORS • PLASTIC SPECIALTIES • CONTRACT PLASTICS MOLDING

One of America's AAAA Industrial Enterprises

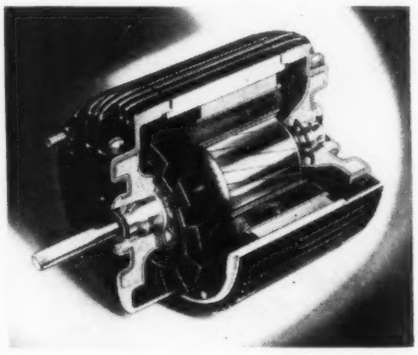


disk on which is printed a 25 in. time scale. The desired schedule of operation is set on the controller by cutting knotches on the time scale. Disks for new cycles or schedules can be made easily. All controllers are drilled for eight cams and pilot valves.

Fractional Horsepower Motors

Redmond Co. Inc., Owosso, Michigan.

Because of circulating lubrication and fin-line functional styling with 198 sq. in. of cooling surface and internal air circulation, these motors will operate

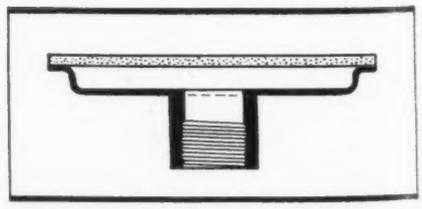


in any position for unlimited periods. The Micromotor is a 1/20 hp., 4-pole shaded pole, totally inclosed a.c. motor designed for continuous fan duty at 1,500 revolutions per minute.

Stainless Steel Spargers

Micro Metallic Corp., 193 Bradford St., Brooklyn 7, N. Y.

These gas dispersion filters are made of a disk of porous stainless steel, which is welded about its periphery to a shallow stainless steel dish. The dish is welded to a standard female pipe connection. The porous elements range in porosity from 5 to 65 microns. The finer grades yield a large volume of tiny gas bubbles. The high flow capaci-



WHEN YOU SEE IT STOPPED YOU *KNOW* IT IS STOPPED

GET THAT AIRLINE MOISTURE BEFORE IT GETS YOUR TOOLS AND CYLINDERS

Corrosive, rust-creating moisture and compressor emulsions that raise merry Hades with fine tools have been getting past conventional air filters.

BUT MOISTURE IS NOW "STOPPED COLD" BY THE NEW NORGREN TRANSPARENT BOWL FILTER — with exclusive "Tornado Jet" and "Quiet Zone" features. *You can actually see the moisture being separated!*

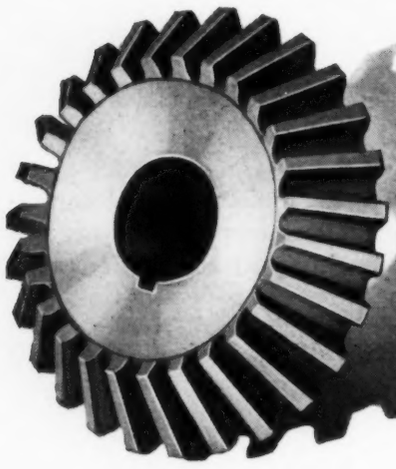
- Directional air inlet (Tornado Jet) imparts swirling motion, separating and throwing moisture against outer wall.
- Moisture runs down below baffle plate.
- Baffle plate divides bowl into ACTIVE and QUIET zones: *active,* where separation takes place, *quiet* where moisture accumulates for draining off instead of being driven along due to exposure to air turbulence.
- Reinforced Monel wire screen stops all solids.
- Transparent bowl lets you *see it work*—shows when liquid and "goo" should be blown out bottom cock.

Norgren

Write for **DETAILED INFORMATION...**

stop gambling with vital air cylinders and tools . . . KNOW that you have STOPPED the damaging moisture. C. A. Norgren Co., 222 Santa Fe Drive, Denver 9, Colorado, U. S. A.

BACKGROUND
FOR *trouble-free* POWER TRANSMISSION



PERKINS GEAR ENGINEERING • SERVICE •

Significantly, many of the country's large-scale buyers of precision gears, whose end-products enjoy international repute, have come to consider our production facilities as vital adjuncts to their own respective plants.

Behind the preferential status we have thus earned among such gear buyers is a valid reason: Our job is — and always has been—the mass-production of top-quality gears to customers' specifications.

Once the customer's specifications are in our files, his re-orders are filled automatically *and deliveries made on time.* As long-established specialists in this field, our background of experience, plus the modern production facilities at our disposal, enable us to do our job eminently well.

You Furnish the Specifications • We'll Produce the Gears!

PERKINS Precision, Custom-Cut GEARS

PERKINS MAKES — In All Materials, Metallic & Non-Metallic
Helical Gears, Bevel Gears, Ratchets, Worm Gears, Spiral Gears, Spur Gears, Ground Thread Worms

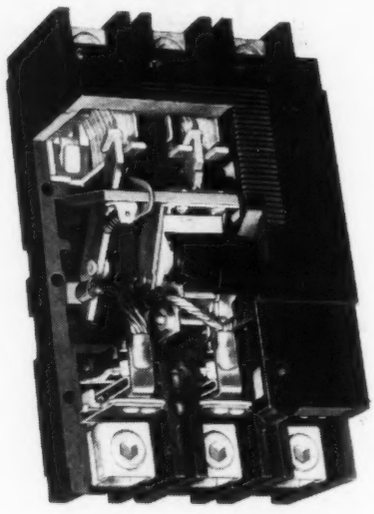
PERKINS MACHINE & GEAR COMPANY • Springfield 2, Mass.

ties of these filters are accompanied by low pressure drops. Porous elements are 1, 1½, 2⅜ and 3½ in., and the pipe connection sizes are ⅛, ¼, ⅜ and ½ inches.

Circuit Breaker

Square D Company, 6060 Rivard St., Detroit 11, Mich.

Known as the Type ML-3, this breaker uses solderless connectors that facilitate the insertion of heavy cable by swinging open the hinged top of the lug. It is only necessary to cut the cable to proper length, remove sufficient insulation from the end and lay



the cable into the lug, snap the hinge top into position and tighten the set screw. The breaker is available in sheet steel, dust resisting inclosures with side operated handle for 3 and 4 wire solid neutral, in addition to 2 and 3 pole devices. The trip ratings are 125 to 225 amperes. The breaker frame is 10⅜ in. high by 6 in. wide.

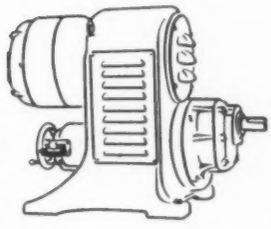
Assembly Glue

Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.

A resin adhesive known as Durez 13793, for assembly or secondary gluing which sets at room temperature and has a one hour assembly time, is used for gluing hard or soft wood, sheet asbestos, foamed glass, phenolic laminates and vulcanized fibers. This resorcinol type adhesive is said to meet all specifications that require a durable boilproof adhesive that sets at temperatures of 70 deg. F. or higher. Durez 13793 is a water soluble liquid resin that is used with a powdered hardener, and will carry extra filler and water without impairing its bonding qualities. Where immediate application of pressure is not practical or desirable, tests indicate a maximum open assembly time

Now...

for a few dollars more you can have *Varidrive* instead of a fixed speed motor



When you select your next motor, pause for a moment and think of all the extra advantages variable speed will give to your machine.

It may surprise you to learn that you can now buy a *U. S. Varidrive Motor* for not too many dollars more than an ordinary motor will cost. But the savings it will return to you will pay and repay this small difference in cost for years to come in many ways.

A *Varidrive* does more than give you thousands of speeds. It gives you precise control that fits the operator's rhythm of movement. It will help synchronize production flow. Your machine will produce more because you can regulate its speed instantly to meet the varying conditions that arise day to day, hour to hour, minute to minute. You'll get more output from your shop labor—a better "frame of mind," less fatigue, complete satisfaction on his part,—because he will be operating with the best for the job.

The *U. S. Varidrive Motor* helps modernize your plant. It's the last word in motor power. It's compact, self-contained, occupies little more space than an ordinary motor—and it enables your present equipment to operate with more scope, at controlled tempo.

If you have never used a *U. S. Varidrive* you can't realize the uplifting effect it has upon the operator, as well as the increased versatility it gives to the driven machine. *So try one.* Put it through the paces. You'll be amazed at what it will accomplish. And bear in mind, its initial cost is little more than just a motor. You can't afford to operate without it.

Speed ranges up to 7 to 1. H. P. ¼ to 15. Built-in gearing available for lower speeds.

Ask for Bulletin F-836

U.S. ELECTRICAL MOTORS Inc.

Atlantic Plant: Milford, Connecticut
Pacific Plant: Los Angeles 54, California

District Offices: Boston 16—New York City 6—Philadelphia 2—Pittsburgh 22—Chicago 8—San Francisco 7—Seattle 4

Sales and Service offices in all principal cities

IMPORTANT
assembly
savings

RECONVERSION TIME is cost-cutting time. Many of the foremost machinery builders are finding that by simply *peeling* precision laminations from Laminum shims, much costly machining is made unnecessary in accurately fitting bearings, gears, etc. These savings are specific, and large enough to be important. Want performance data?

Laminum shims are cut to your specifications. For maintenance work, however, stock shim materials are sold through industrial supply houses.

Laminated Shim Company, Incorporated.
63 Union Street • Glenbrook, Conn.

LAMINUM
TRADE MARK
THE SOLID SHIM THAT peels FOR ADJUSTMENT

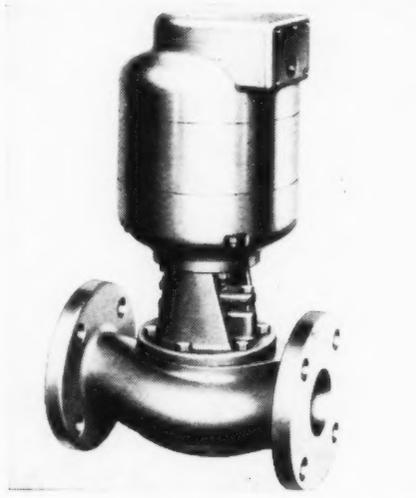
2213

of one hour and closed assembly time of 2½ hours at 70 deg. F., or ¾ of an hour open assembly and 1¾ hours closed assembly at 90 deg. Fahrenheit. With these assembly times, maple block tests indicate a shear strength of at least 2,800 pounds per square inch.

Circulating Pump

The Ruthman Machinery Co., Cincinnati 2, Ohio.

The driving motor, direct connected to the Rumaco circulating pump, Model 1-B, is a totally inclosed type equipped with grease packed, sealed precision ball bearings. As no added lubrication is necessary, all oilers and grease fittings have been eliminated. The motor stator

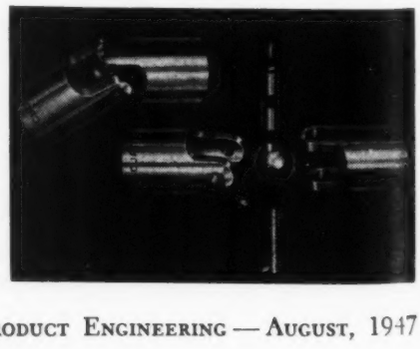


is dynamically balanced by a dynetric process to close limits giving quiet and vibrationless operation. The pump, built on centrifugal principles, is made with opposing inlet and outlet for standard 2 in. pipe flanges. The unit can be installed with pipe reducers, and can be operated at any intermediate angle between a vertical and horizontal position.

Universal Joint

Curtiss Universal Joint Co. Inc., Dept. D, Birnie Ave., Springfield 7, Mass.

In this ball type universal joint, sliding friction is eliminated and bearing friction minimized, making the use of boots, covers and excessve lubrication unnecessary. Tests have shown this design to be useful for high speeds at



AN EXAMPLE:

This is a diesel engine exhaust manifold outlet fabricated with Tube-Turn welding fittings taken out of regular stock. Replacing castings—eight such outlets to an engine save .71 lbs. per horsepower. Seems little, but multiply this by 1000 and you have 710 pounds of dead weight eliminated.

"It can be done!"

SO MANY piping problems are solved with the use of welding fittings that it pays to see your Tube-Turn Distributor first. He handles *the fitting that becomes part of the pipe.*

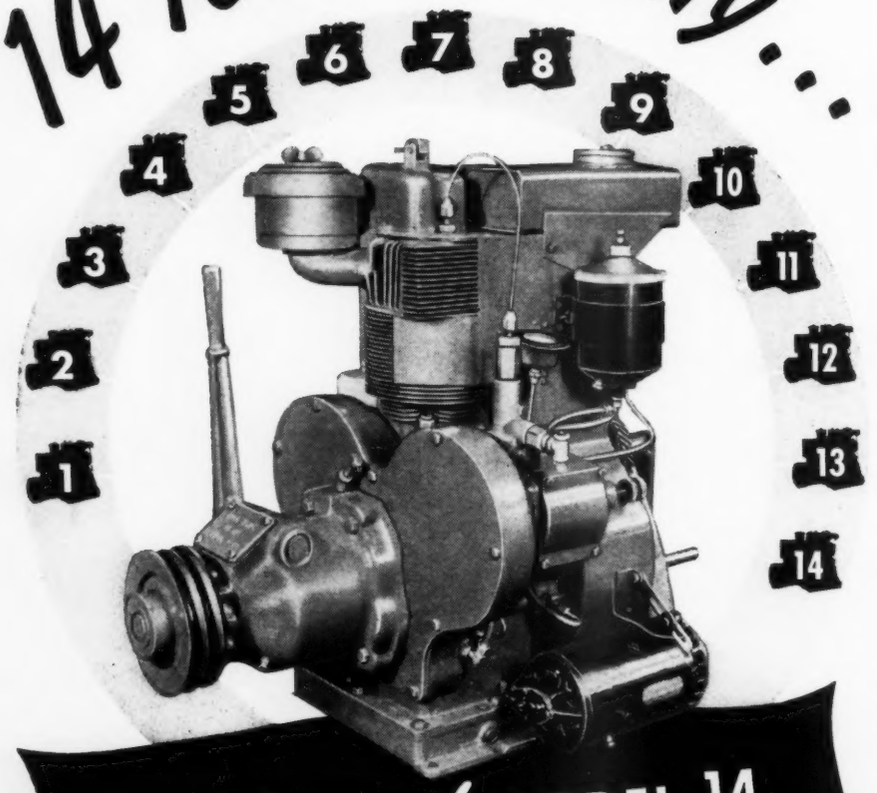
Tube-Turn welding fittings—engineered in design, built with closer tolerances than code requirements, available in a wide variety of styles, sizes and materials—often offer just the right answer to what sometimes seems an impossible problem. Welding fittings for example, permit extremely close nesting without flow loss. Tube-Turn welding fittings have uniform wall thickness and full circularity which allows them being cut and used at odd angles. Order one, one-hundred, or a thousand Tube-Turn welding fittings of the same size and part number and they will be dimensionally uniform. They can be and are being used in production line assembly of equipment.

For full information about the more than 4000 types and sizes in the complete line of Tube-Turn welding fittings and flanges—for details about the wide range of special metals and alloys—for the name of your nearest distributor, write to—

TUBE TURNS, INC., LOUISVILLE 1, KENTUCKY
District Offices at New York, Washington, D. C., Philadelphia, Pittsburgh, Detroit, Chicago, Houston, San Francisco, Los Angeles.

TUBE-TURN TRADE MARK **tt** *Welding Fittings and Flanges*

14 reasons why...



A Sheppard MODEL 14 AIRCOOLED DIESEL WILL IMPROVE YOUR PRODUCT

Smooth Operation—Requires very little attention. No operating adjustments.

Air Cooling—No cooling liquid to check. Anti-freeze precautions are unnecessary.

Dependable Operation—Delivers 3½ *continuous* h.p. day in and day out.

Economical Fuel—Uses low-cost domestic furnace oil for fuel. Fuel costs average about 2c to 3c per hour.

Quick Starting—Just set the throttle and push the electric starter button. Can also be hand started.

Portable—Air cooling reduces weight and bulk.

Ease of Maintenance—Any practical man can do it himself.

Inexpensive Upkeep—Minimum down-time necessary. Full diesel operations eliminate cleaning and servicing spark plugs and carburetor.

Easily Serviced—Only routine lubrication and refueling is required.

Stable Output—Exclusive Sheppard Governor maintains constant speed from no load to full load. Better than 3½% governor regulation.

Takes Minimum Space—Compact design makes it readily adaptable.

No Electrical Ignition—Spark hazard is eliminated. Operates efficiently in the open regardless of weather.

No Carburetor Needed—Fuel is injected in a solid stream for even, complete combustion. The simplified Sheppard fuel injector system has only one moving part.

Greater Safety Factor—Diesel fuel is non-explosive... safe to handle and store. Operation in a normally ventilated building is perfectly safe.

We would like to show you how the use of the Sheppard Model 14 *Aircooled* Diesel Engine can make yours a greater product or simplify the design of new equipment. Write for complete specifications and descriptive literature.

R. H. SHEPPARD COMPANY, INCORPORATED
91 Middle St., Hanover, Pa.

Sheppard DIESEL

DIESEL'S THE POWER...
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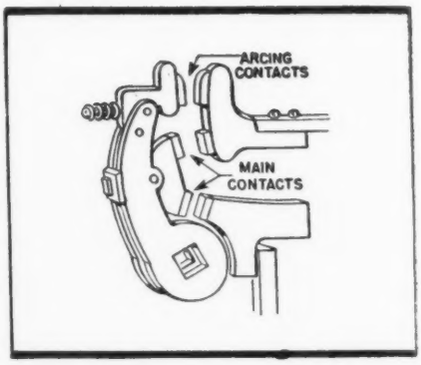
light loads. The forks of this ball type joint are steel and bear on a bronze ball, with heat-treated centerless ground pivot bearing pins. The large pivot pin is built with an oiler that enables proper lubrication to reach all bearing points. The joints are available with ½ and ¾ in. diameters.

Electrical Contacts

Gibson Electric Co., 8358 Frankstown Ave., Pittsburgh 21, Pa.

Silver-molybdenum contacts are supplied in two grades: Gibsiloy M-10 and Gibsiloy M-12, the latter containing a higher percentage of molybdenum. Because of its high refractory content, M-12 is used on heavy circuit breakers where greater mechanical and electrical stresses are encountered; M-10 is used on smaller sized circuit breakers handl-

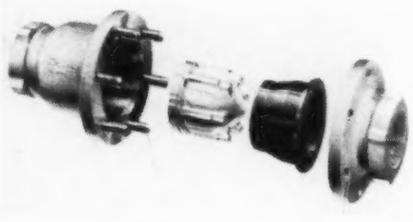


ing lower pressures. These contacts are suitable for use as arcing tips in either air or oil circuit breakers. Made by the powder metallurgy process, Gibsiloy contacts combine high hardness with good conductivity. These contacts are made in individually molded shapes for each application and are furnished solder-backed for convenient and dependable brazing.

Check Valves

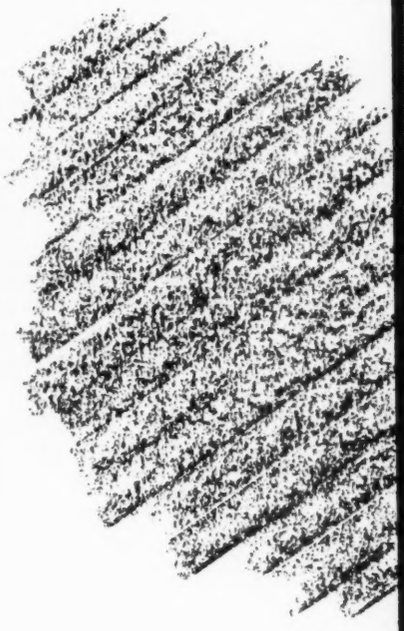
Grove Regulator Co., 65 & Hollis Sts., Oakland, Cal.

The outstanding component of the Chexflo Valve is its tough flexible tubular operating member. This member is made with a thick load section tapering to a sensitive operating lip, which requires no differential pressure to effect positive bubble-tight shut-off. The tapered synthetic rubber lip freely expands to open, allowing unrestricted



A NEW I. D. FOR YOU

Now, a ready-to-use Wolverine Trufin



You no longer need to perform costly stripping or expanding operations on Wolverine Trufin tube prior to making end connections. Instead, the Inside Diameter of Trufin is controlled; and inserted end connections can be easily and economically made by brazing any standard tube into THE integral finned tube. You can readily utilize any length or random lengths by simply cutting Wolverine Trufin to meet your requirements.

All connecting tubes, whether flared, threaded, bent, etc. can be assembled to Trufin without any additional preparation.

Send for our new Form S-651, which gives complete specifications and other helpful information about Wolverine Trufin—THE integral finned tube.

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CALUMET & HECLA CONSOLIDATED COPPER COMPANY

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streamline flow. Because of its resilient elasticity, it contracts smoothly on slack flow; prior to the start of back flow. In both the open and closed positions, it is supported against extreme pressure or intensive impulse shocks by the inner walls of the valve body, and the cylindrical acorn-shaped core that it tightly incloses. As it reaches shut-off position, flow velocity increases which flushes the seating surface of any small particles. The flexible tube absorbs all shock impulses.

Universal Gear Motor

John Oster Mfg. Co., Racine, Wis.

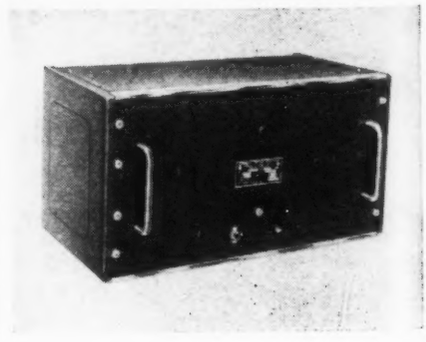
The type DUR-531 Universal gear motor has a totally inclosing die-cast motor housing. The worm gear is made of laminated bakelite and the gear housing is grease packed for thorough lubrication. The armature and field windings are doubly impreg-

nated and baked. The armature bearing on the commutator end is a grease sealed ball bearing. The gear motor operates on 115 volts, a.c. or d.c., developing a torque of 3.7 in.-lbs. at 120 rev. per min., for intermittent duty. Direction of rotation is clockwise when looking at the output shaft.

Voltage Regulator

The Superior Electric Co., 5107 Laurel St., Bristol, Conn.

A completely electronic device with no moving parts, the Stabiline type IE 5101 corrects line voltage fluctuations



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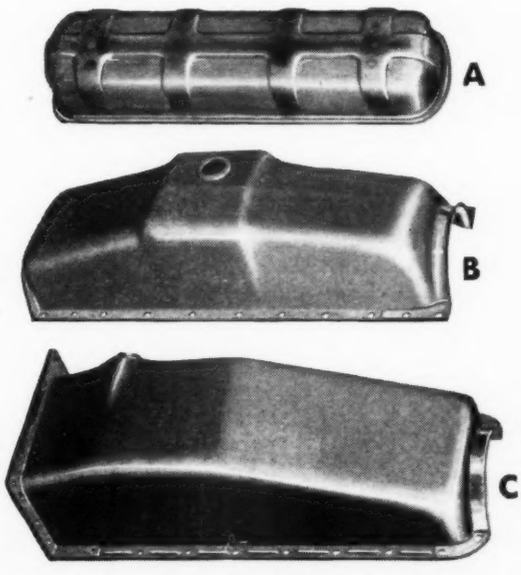
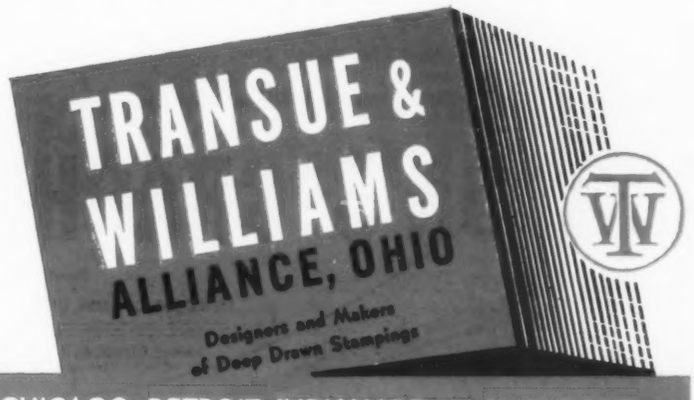
It's as simple as that . . . the reason why Transue ranks as a preferred source of deep drawn stamping parts among many prominent users. Readily available without slightest obligation, Transue's consulting service on technical problems of stamping application is provided by engineers and designers with extensive experience. Exceptionally complete working facilities (which include double action presses up to 650 tons, auxiliary presses of many types; pickling, annealing and welding equipment) permit production geared precisely to the customer's needs. This means highest quality, close tolerance parts, delivered on schedule. Why not try Transue?



A—ONE-DRAW CYLINDER HEAD COVER; 19-1/8" long, 3-1/2" deep.
B—TWO-DRAW OIL PAN; 28-5/32" long, 7" deep.
C—TWO-DRAW OIL PAN; 26-21/32" long, 8-1/16" deep.



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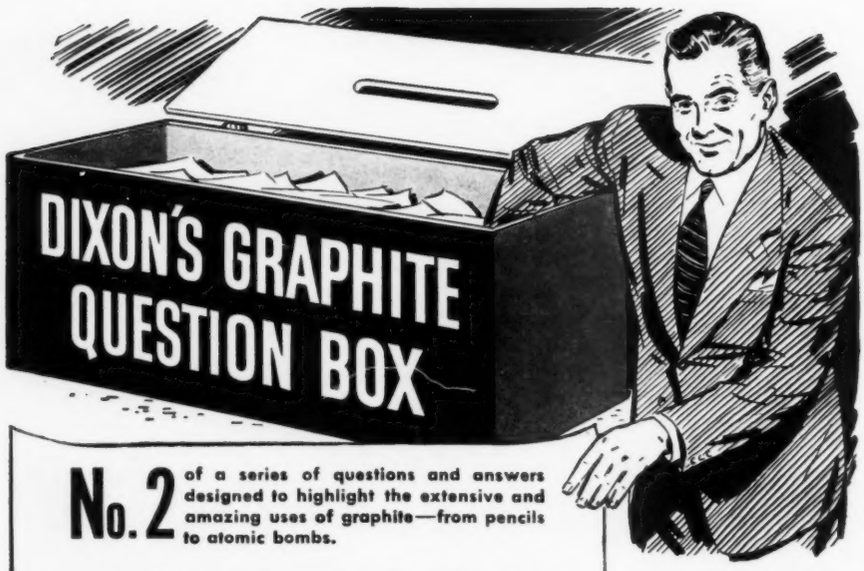


No. 2 of a series of questions and answers designed to highlight the extensive and amazing uses of graphite—from pencils to atomic bombs.

HELPFUL ANSWERS FOR TECHNICIANS AND PRODUCT ENGINEERS

QUES. What are the principal characteristics of graphite?

ANS. Extremely unctuous. Lustrous and opaque. Withstands excessively high and low temperatures. Fusibility unknown but probably about 3000° C. Combustible in the presence of oxygen at about 620° C., but not altered by heating in a vessel free from air. Chemically inert. Good electrical and heat conductivity. Low co-efficient of expansion. Non-magnetic, non-fusible, non-toxic, non-odorous, and does not permanently stain. Specific gravity: 2.1 to 2.3. Moh's scale of hardness: less than 1.

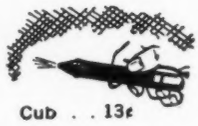
QUES. What are *some* of the products or processes in or on which graphite is used?

ANS. Tungsten and molybdenum wire filaments
Steam and internal combustion engine cylinder lubricants
Hydraulic pump piston and piston rod lubricants
Extreme heat-and-pressure-resisting lubricants
Mechanical packings and gaskets, washers and sealing rings
Pipe joint compounds and seals
Brake linings
Paper (lubricating and transfer)
Typesetting machine mold, space band and mouthpiece lubricant
Wire drawing
Oil-less, self-lubricating bearings
Transmission chain lubricant
Transmission rope and cordage lubricants
Trolley wire lubricants
Protective surface coatings with lubricating qualities
Impregnated lubricating metals, plastics, rubber, felt, fabrics, leather, paper and wood
Lubricating bearing paste
Mechanical oven, lehr and kiln chain lubricants
Metal stamping, forging, tumbling and assembling lubricants
Lathe dead center and steady rest lubricant
Rolling mill lubricants
Quarry and mine machinery lubricants
Coal mine machinery lubricants
Lock lubricants
Firearm action and barrel lubricants
Cycle chain lubricant
Piano action and organ assembly lubricants

(To be continued in No. 3)

A few of thousands of widely used products containing Dixon's Graphites. Those starred are Dixon's products, many of them sold by supply houses everywhere.

★Microfyne Flake Graphite



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★Graph-Air Guns

Mechanical Packings

Now may we receive *your questions* on how graphite can help *you*?

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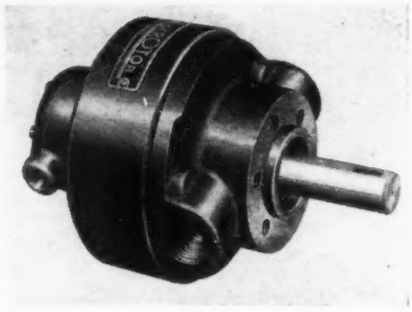
in this series. We will gladly send you reprints of any you may miss

with no more than 3 percent waveform distortion. The output voltage, for any load up to rated 1 kva., is held to within ± 0.1 volts of any nominal value in the output range between 110 to 120 volts for an input line voltage change from 135 to 95 volts. The regulator is not affected by any load change from zero to full rating, and is independent of any load power factor change from a 0.5 lagging to a 0.9 leading current.

Hydraulic Motors

Gerotor May Corp., Maryland Ave. & Oliver St., Baltimore 3, Md.

Using the basic Gerotor principle with its low relative speed of the two elements, the newly developed motors efficiently convert hydraulic power into rotary power. These motors can be stalled under load without damage,

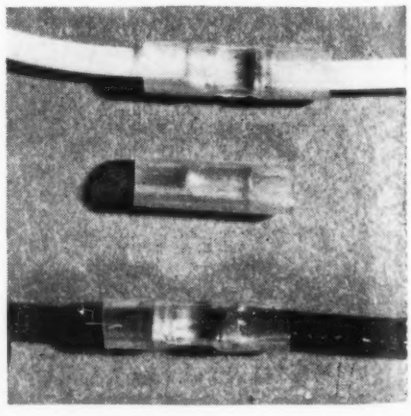


operated safely in explosive and corrosive atmospheres, and installed in small spaces. Their low rotational inertia gives infinite, rapid changes in shaft speed and direction. These motors are available with plain, base or flange mounting, for direct coupling, belt, chain or gear drives, in sizes up to 8.7 horsepower.

Electrical Connectors

Thomas & Betts Co. Inc., 36 Butler St., Elizabeth 1, N. J.

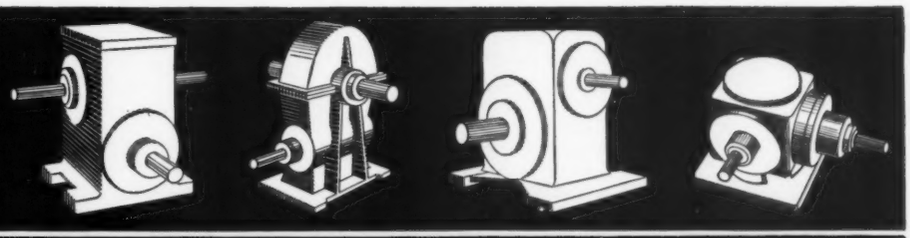
Sta-Kon pressure connectors, the No. 25 insulated splices, are made of seamless bronze protected by a translucent, high dielectric, plastic insulator that is impervious to oil, grease, water,



What Speed Reducer shall I use?

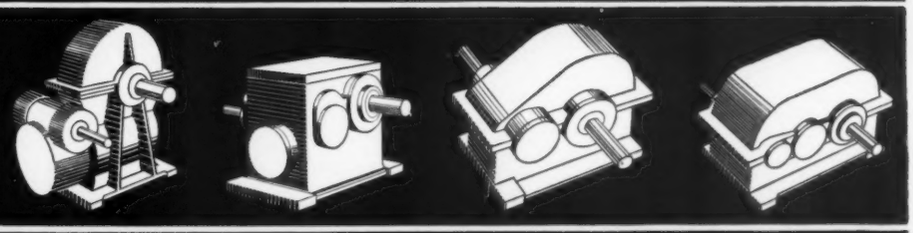
FOR RIGHT ANGLE DRIVES

When you want your driving or motor shaft at right angles with your driven shaft, use any one of these Boston Reductors. Select from these four types depending upon the horsepower or ratio required and the proper type for your application.



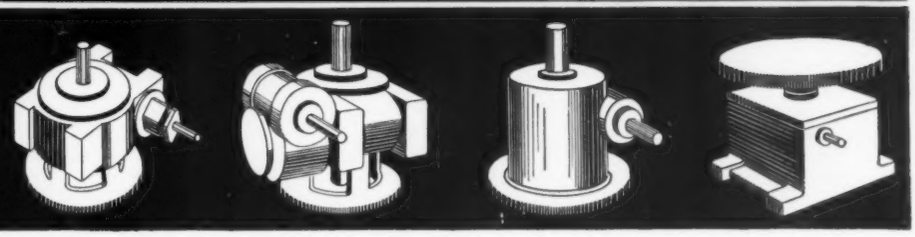
FOR PARALLEL SHAFTS

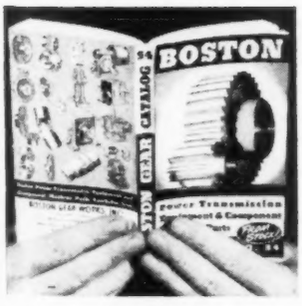
If you desire your driving or motor shaft to be parallel with your driven shaft, use one of these four types. These first two types are double reduction worm and worm gear drives with gear ratios from 16 to 1 as high as 4000 to 1.



FOR VERTICAL DRIVES

You may want a vertical reduction unit for a mixer, conveyor, etc. or where your driven shaft must be vertically up and/or down. These first three types will give you such a versatile drive. The fourth type is strictly a turntable only.





SELECTION A 12-page Reductor or Speed Reducer Selection Chart is included in our General Catalog 54. It contains complete selection data on our Reductors and gives output speeds and gear ratios available, as well as the horsepower motor to use on the Input Shaft of the Reductor. This Selection Chart includes practically all ratios, types and stock sizes available.

DIMENSIONS Complete specifications and dimensions on all Boston Reductors are given in our Catalog 54. If you have a copy of this catalog, you can easily design your drive from the complete dimensions we give you. On some of our Reductors, dimensions are given for elongated Output Shafts which are available as standard assembly. In other cases our speed reducer shafts can project in various other positions as indicated in our catalog.

ORDERING Each and every Boston Reductor has a Catalog Number. No ordering by complicated details after you select whatever ratio, size or type of Reductor you desire. Simply order by Catalog Number.

GENERAL CATALOG If you have need for any speed reduction units in your plant you should have a copy of our 320-page General Catalog 54. It contains complete specifications, dimensions and list prices on all our Power Transmission Equipment and Component Machine Parts — 50 pages of this catalog being devoted to the 12 Reductor types shown above.

BOSTON GEAR WORKS, INC., NORTH QUINCY 71, MASS.

Please send me.....copies of your General Catalog 54.

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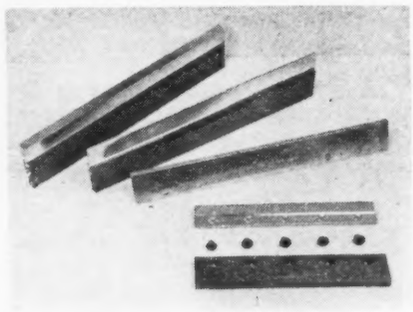
chemicals and acids. The insulator is bonded to the connector and cannot slip or become accidently detached. A single squeeze of the installing tool permanently connects both wires and insulates the connection formed by this splice. They are available in various sizes to take two wires of the same, or different, gage.

Centerless Grinder Blades

Foulk Mfg. Co., 4208 *Airport Rd., Cincinnati* 26, *Ohio.*

Ampco Bronze centerless grinder blades can be used when grinding stainless steel, monel, aluminum or other materials that will "pick up" or score

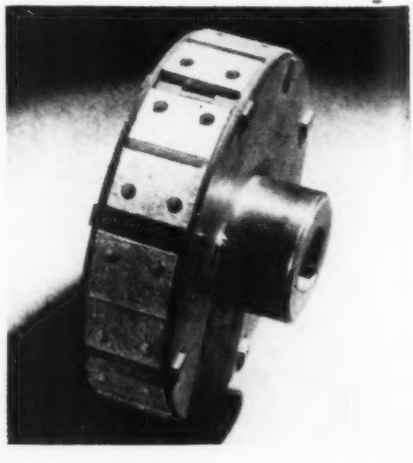


easily. Large feed angles and regulating wheel speed can be used when these blades are used. Ampco bronze blades will generally outwear cast iron blades but are built with renewable insert wearing edges. Blades are available to fit most Cincinnati Centerless Grinder work rests.

Mercury Clutch

Mercury Clutch Corp., Canton 6, Ohio.

A mercury-actuated clutch makes possible automatic starting of air compressors. This clutch permits the driving motor to attain full speed before the compressor turns, eliminating the need for pressure release valves. The "time delay" factor lets the motor utilize its greatest torque and the inertia of its rotor to start the load. Centrifugal



QUICK, SURE PROTECTION for stainless steel during fabrication

From shipping crate to finished product, makers of stainless steel tanks for the dairy, edible oil, chemical and other industries give the finish of their material complete protection.

"SCOTCH" Extra Strength Masking Tape in the 8-inch width, is applied to the steel sheets before they are removed from the crate. It remains on during all fabrication operations—giving complete protection against the scuffing of workmen's shoes, and possible scratching by the compressed air lines, welding and grinding tools dragged over it.

When fabrication is completed "SCOTCH" Extra Strength Masking Tape—Low Tack—strips off readily, leaving the surface of the steel bright and unmarred.

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SCOTCH BRAND
EXTRA STRENGTH
Masking **TAPE**
LOW TACK

Made in U.S.A. by
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THE 3M COMPANY
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Surface • Sphericity • Precision

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Machines used in final lapping operation on medium and large Strom Balls.

It takes a long series of processes, developed and perfected over a period of years, to make a thing as faultless in material and form as a Strom Metal Ball. Worked to a tolerance of fifty millionths of an inch, their outstanding qualities of finish, sphericity and precision have made Strom Balls the standard of industry. Strom Steel Ball Co., 1850 So. 54th Ave., Cicero 50, Illinois.

Strom BALLS Serve Industry

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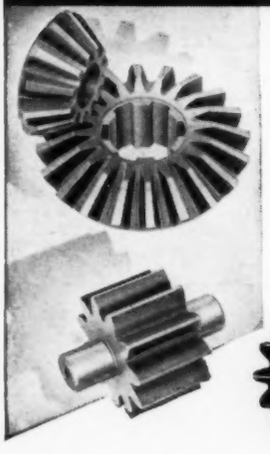


Spur—bevel—spiral—zerol—worms and worm gears—racks—sprockets. All are precision cut on up-to-the-minute equipment exactly to your specifications. *Prompt quotation upon receipt of your sample or blueprint.*

E. B. SEWALL MANUFACTURING CO.

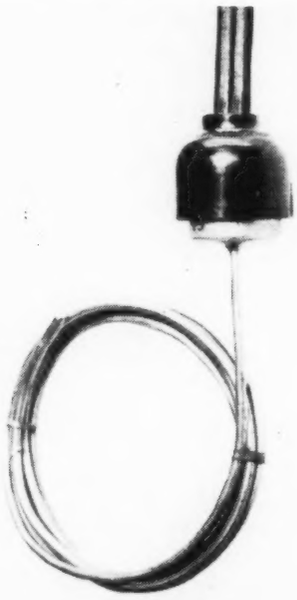
696 Glendale St. St. Paul 4, Minn.

force acting on a small amount of mercury produces hydraulic pressure that is dependent on the head of mercury rather than the amount. This pressure is applied without the use of levers or other mechanical means, to cause the engagement of the friction elements of the clutch. Standard clutches are available for all types of electric motors up to 15 hp., and for internal combustion engines.

Alarm Switch

Cutler-Hammer Inc., 315 N. 12th St., Milwaukee 1, Wis.

This Cutler-Hammer Freezer Alarm Switch is built to warn of mechanical difficulties when the temperatures in



commercial and home freezer units rise to a predetermined danger point. It can be used in connection with a bell, buzzer or signal light alarm system. It operates on a low voltage.

Gas Analyzer

Gow-Mac Instrument Co., 22 Lawrence St., Newark 5, N. J.

This unit provides an accurate and inexpensive means of observing gases by the thermal conductivity method. The Gow-Mac unit is flexible in gas train sampling and is used with standard laboratory instruments and accessories. Units may be used with indicating, recording, or controlling instruments. Filaments in each of four chambers are wired together to form a balanced bridge. Each of the elements has a predetermined resistance. When used with a suitable source of constant voltage, the degree of unbalance of the bridge circuit gives an accurate measure of the relative thermal conductivity

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Allcast was officially announced in January 1946. Its widespread acceptance by industry has demonstrated the need for such an alloy. Allcast, now covered by the above Specifications recently established for alloys of this type, assures these exceptional advantages:

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For the engineer — Affords superior mechanical properties. The engineer can advantageously specify Allcast for many applications. A few typical ones are: internal combustion engines, tire molds, hydraulic machine castings, truck wheels, washing machine parts, match plates and core boxes, motor frames, portable machine tools.

For the final user — To the finished product Allcast contributes the advantages of lightweight, good appearance, soundness and rigidity, while avoiding the higher cost of premium priced metals.

A new bulletin on Allcast Aluminum Alloy is now available, giving latest information on its unusual properties. Write and we shall be glad to forward your copy promptly.

THE NATIONAL SMELTING COMPANY
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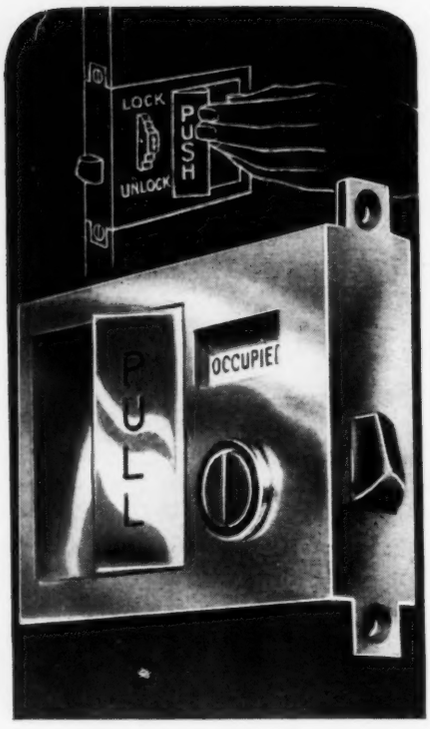
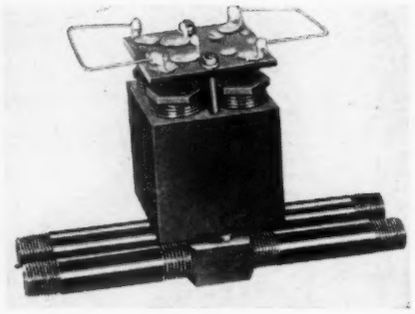


SELF-
Rivalry

Self-competition, constantly seeking better design and thriftier production, results in continuous advancement of product and purpose. Witness the Compartment Door Lock #AR20 shown above—more compact, lighter in weight, yet half the cost of its predecessor which we first created. Here is tangible evidence of why Adams Rite remains prime source for nearly all locks and latches used on large aircraft. Our independent approach to locking problems enabled us to foster the present trend toward standardization within the industry . . . today it's Adams Rite for nine out of ten!

Quality Hardware
for Nearly a Half Century.

ADAMS-RITE MFG., CO.
540 WEST CHEVY CHASE DRIVE, GLENDALE 4,
CALIFORNIA, U. S. A.

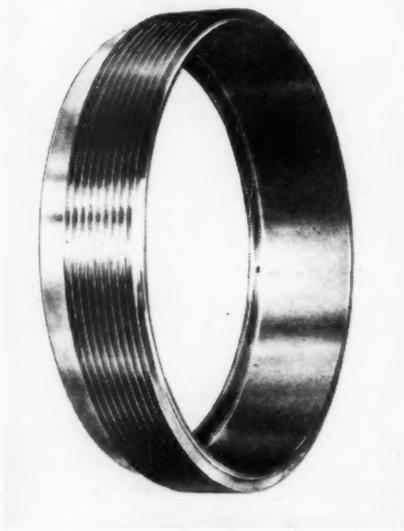


of an unknown gas, or the quantitative variation in a known gas. The Gow-Mac unit measures 1½ x 3½ x 2⅜ in., and all parts are precision machined. Each cell is pressure-tested at 10 lb. per sq. in. prior to delivery.

Brake Drum

Copperweld Steel Co., Glassport, Pa.

This brake drum has a friction surface of special wear-resisting alloy steel and an outside layer of copper with specially designed fins. Because of the high thermal conductivity of the copper, the brake drum dissipates friction-generated heat to the atmosphere at a rapid rate;



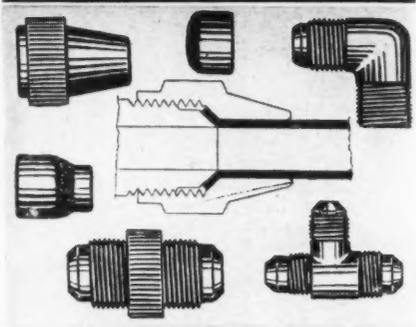
at the same time maintaining a more uniform temperature level over the entire brake drum surface. The advantages claimed for this brake are lower temperatures, resulting in virtually no heat checking; no cracking; less wear on blocks and drums, and freedom from distortion.

Brazing Paste

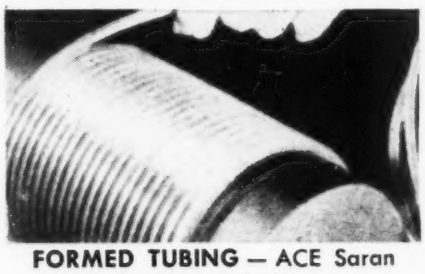
Sherman & Co., 197 Canal St., New York 13, N. Y.

A paste developed specifically for brazing carbide tips, Nu-Braze silver alloy Diffusion Paste No. 50, is made of a new silver brazing alloy finely pulverized and then ground with a special flux. The flux begins to melt at 480

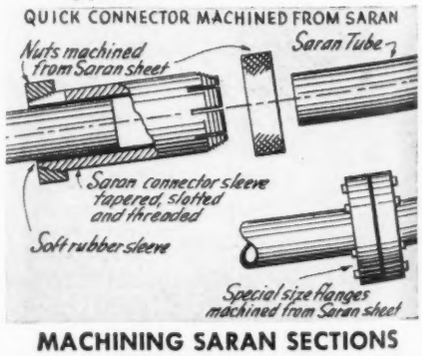
Design Hints
FOR
ACE SARAN
TUBING & FITTINGS



FLARED FITTINGS make possible any hook-up required for corrosion-resistant lines for cooling water, coolants, chemicals, hydraulic controls, electrical conduit.



FORMED TUBING — ACE Saran can be formed much the same as metallic tubing for a wide variety of applications.

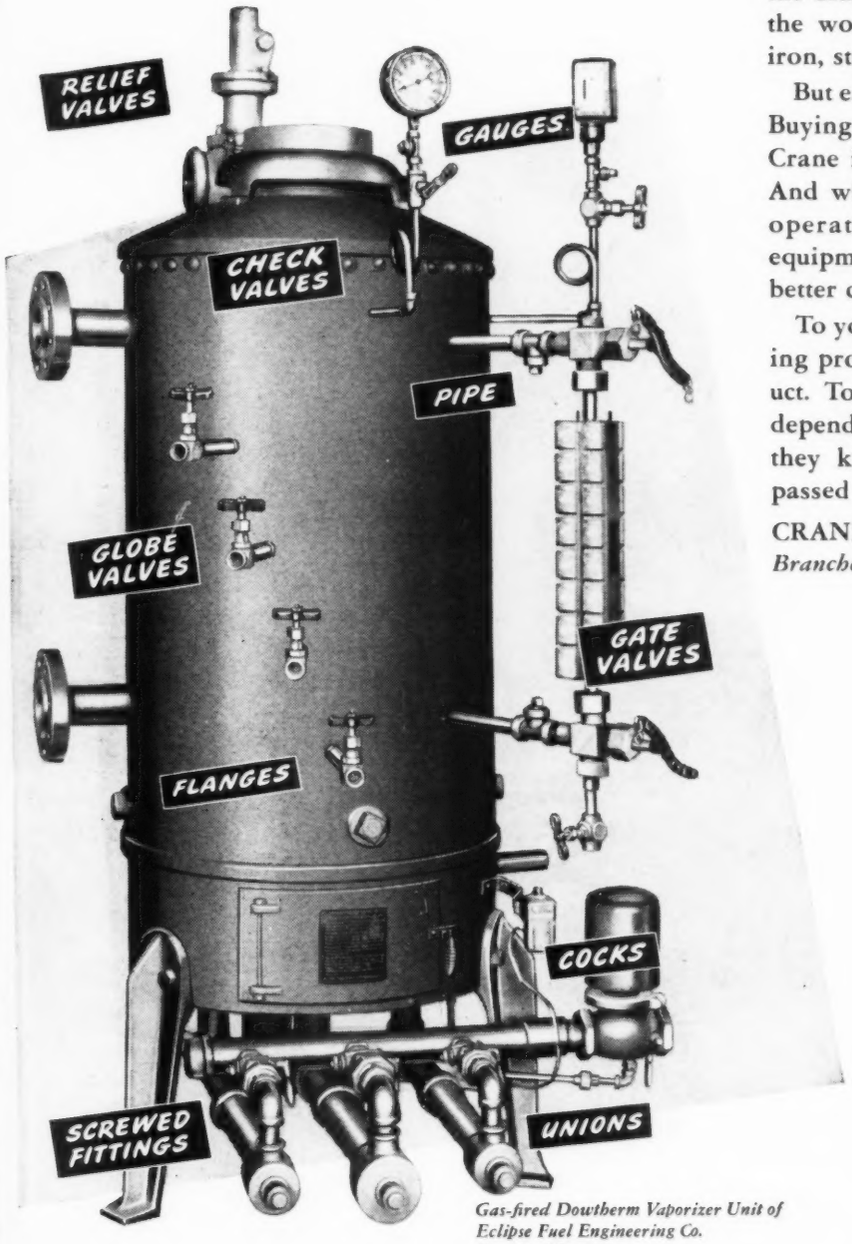

QUICK CONNECTOR MACHINED FROM SARAN
Nuts machined from Saran sheet
Saran Tube
Saran connector sleeve tapered, slotted and threaded
Soft rubber sleeve
Special size flanges machined from Saran sheet

MACHINING SARAN SECTIONS —Many times it's more economical to machine parts from standard sections than to make molding dies. Consult ACE.

IF IT'S MOLDED OR EXTRUDED
Specify ACE
and send your drawings to
AMERICAN HARD RUBBER COMPANY
11 MERCER STREET, NEW YORK 13, N. Y.

Everything you need in Piping ...in One Complete line

ONE
SOURCE OF SUPPLY
RESPONSIBILITY
STANDARD OF QUALITY



Gas-fired Dowtherm Vaporizer Unit of Eclipse Fuel Engineering Co. Equipped by Crane.

Does the design on your board involve flow control? Then make sure you'll have no trouble with piping equipment—specify Crane Quality. In the Crane line, you'll find everything you need—the world's most complete selection of brass, iron, steel, and alloy piping materials.

But ease of specifying isn't the only advantage. Buying and storekeeping are simplified, since Crane is the sole source of your piping needs. And when you get down to product assembly operations, single responsibility for piping equipment means trouble-free installation, and better control of factory schedules.

To you, Crane means swift progress in all piping procedures from blueprint to finished product. To your customers, Crane means uniform dependability in flow control equipment. For they know that Crane Quality stands unsurpassed for 90 years.

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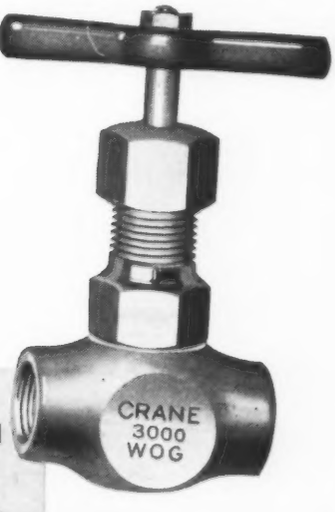
(*Below*) **STEEL VALVES OF SOLID BAR STOCK** *for gases and liquids up to 3,000 lb. cold working pressures. Sharply tapered plug type disc gives finest flow regulation. Wide seating surfaces insure tight closure; resist wire drawing and foreign matter damage. In Exelloy for high resistance to atmospheric corrosion, and for handling oil or gas containing sulphurous compounds. Also made in 18-8 Mo and Carbon steels. Globe and angle, male and female end patterns, in ⅛ to 1-in. sizes. See Crane Catalog, page 310.*



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PIPE • PLUMBING
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CRANE

FOR EVERY PIPING SYSTEM

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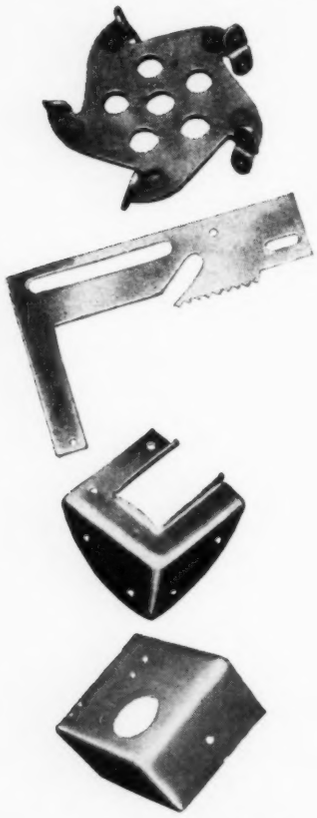
Are your sales suffering because your product weighs too much? Is your capacity limited because of the manufacturing process involved? Are your production expenses up because of high material costs? . . . Any or all of these problems *might* be solved by using the right metal stamping where you're now using another type of construction.

Paul and Beekman, Inc. *knows* metal stampings. We produce them in all types —from mild steel, stainless, copper, aluminum and brass. We make them fast and we make them right, because we have the plant, the personnel and the organization to do just that.

If you think the use of precision stampings might enable you to put out a better product, faster, at less cost . . . call on Paul and Beekman, Inc. Write us for literature explaining our complete service.



PAUL & BEEKMAN, Inc.

18th & Courtland Sts., Philadelphia, Pa.
Subsidiary of Portable Products Corporation

deg. F. and protects both the carbide tip and the steel joint area with a liquid film before the heat-generated oxides can form. The viscosity of the flux is so low that the molten brazing alloy component gently eases all of it out of the joint. The paste is painted on the joint surfaces with a small brush. The parts are then assembled and heated.

Tumbler Switches

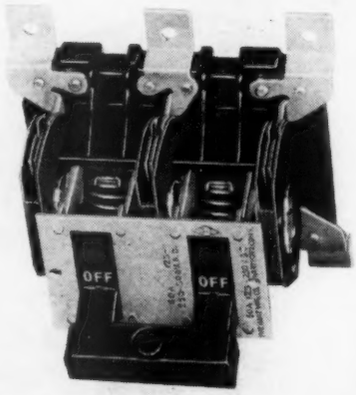
The Hart Mfg. Co., 108 Bartholomew Ave., Hartford, Conn.

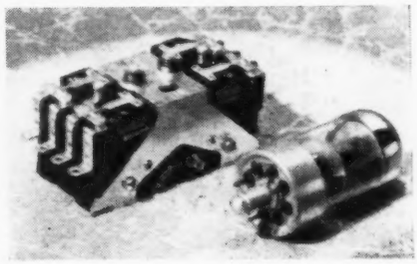
Designated as Diamond H, Type TU Switches, these tumblers are heavy-duty, 1-, 2- and 3-pole switches. They are fast breaking and non-arcing, and are rated at 60 amps. up to 250 volts d.c. and up to 500 volts alternating current. They are suitable for heavy marine usage and can be used on domestic and industrial circuits.

Latching Relay

Sigma Instruments, 70 Ceylon St., Boston, Mass.

As the entire moving system in the multicircuit switching relay, Type 6FZ2A2B, is dynamically balanced, while operating with detent forces of over 200 in.-g., freedom from the effects of vibration and shock is obtained. Mechanical wear does not lessen, if anything it increases, the latching stability. Each of the eight individual





switch positions, which may be normally open or closed, carry a nominal rating of 5 amp. at 110 volts a.c. or 24 volts d.c., although actual ratings vary with life requirements and char-

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A MICRO HUMIDITY RECORDER

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ACCURACY — Within ±3%

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THE LABORATORY HYGROMETER

Type HGS — HY 1

ACCURACY • SENSITIVITY
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SERDEX INC., 91 Cambridge Street, Boston 14, Mass.

Dayton Multiple V-Belt Drive transmits power to sand conditioning blade

Drudgery of sand conditioning—the painfully slow method of shoveling—has been replaced by a modern, mechanized method. Now, a lawn mower type, cutting blade cylinder does the work easily, more uniformly. For fast, smooth and dependable power flow the designer specified a Dayton V-Belt Drive. And, as a result, uniform sand conditioning increases foundry production of better castings . . . at less cost per unit.

This is another of the many examples of the flexibility of Dayton V-Belt Drives. The capacity of Dayton V-Belt Drives to perform in excess of standard requirements—under all operating conditions—is another of the many reasons more industrial designers *consistently* specify *Daytons* for original equipment. A Dayton Power Transmission Specialist is ready to help you. Call or write: DAYTON RUBBER · DAYTON, OHIO.

NOW! * *Rayon Cords*

PROVIDE DAYTON V-BELTS WITH

1. Minimum Stretch 2. Greater Flex Strength 3. Longer V-Belt Life

* Rayon cords are *specially processed* by Dayton for use in V-Belts to provide the most efficient and economical power transmission service for your machine needs. For the complete story write for booklet A-469.

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THE MARK OF TECHNICAL EXCELLENCE IN NATURAL AND SYNTHETIC RUBBER

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THE *Proved and Approved* METHOD
of making wire connections

Ideal "Wire-Nuts" are rapidly replacing old-fashiond methods wherever wire connections are made. Millions are being used in new construction, remodeling and re-wiring . . . in repair work . . . in the manufacture of electrical goods . . . and in the installation and maintenance of electrical equipment. *Effect real savings.* "Wire-Nuts" are made in sizes for all usual wire combinations. Factory tested and inspected. *Reduced prices now in effect.* Order from your Electrical Wholesaler today!

* *Trade Mark Reg. U.S. Pat. Off.*

PATENTED

"Wire-Nuts" are covered by *U. S. Patent No. 1,933,555,* a division of U.S. Patent No. 1,700,985. The only Connectors authorized to be sold under the current Patent are marketed by the following manufacturers:

	TRADE NAME
Ideal Industries, Inc.	"Wire-Nuts"
Bryant Electric Co.	"Bryant"
Solar Electric Corp.	"Scru-its"
Weiss & Biheller, Inc.	"Simplex" and "Conex"

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IDEAL INDUSTRIES, Inc.
Successor to Ideal Commutator Dresser Co.
1446 PARK AVENUE, SYCAMORE, ILL.

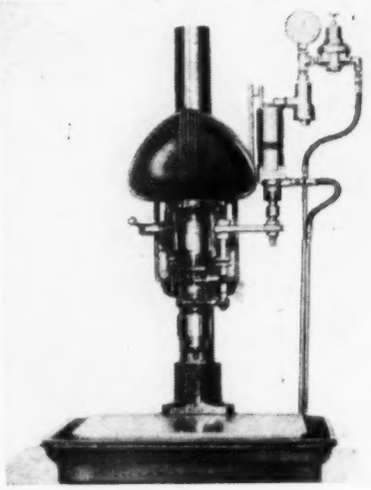
Distributed Through
AMERICA'S LEADING WHOLESALERS

acter of load. Contacts may be ganged or arranged in pairs to a maximum of four double-break circuits. Coils, which operate from direct current, require pulses of less than 0.5 watts for tripping, and are available with resistances up to 10,000 ohms.

Pneumatic Operating Equipment

National Pneumatic Co., Graybar Bldg., New York, N. Y.

Supplied as Drill Press Kit No. DC-40730, this pneumatic operating equipment is made up of an operating assembly; including air engine, pressure gage, pressure regulator, exhaust valve and cushioning plug; a foot operated

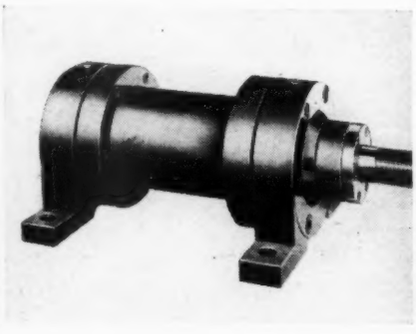


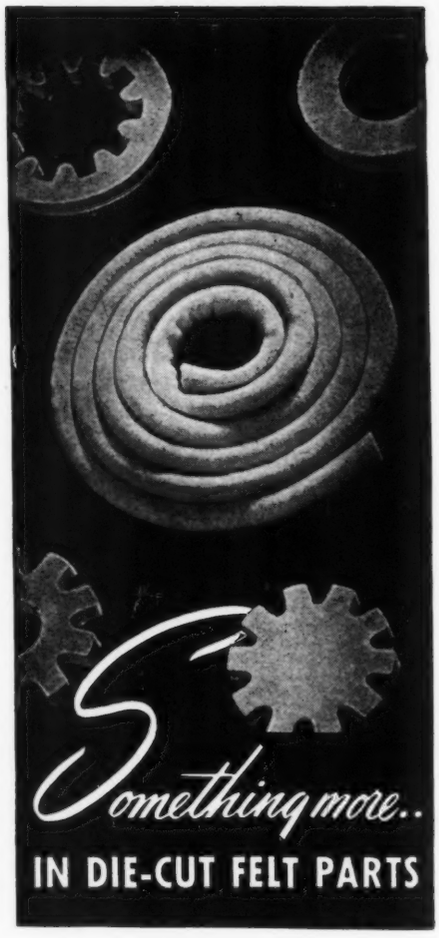
control valve; air strainer; cut-out cock and flexible hose. This kit converts drill presses to air-powered operation. There are kits designed for use on many other types of equipment. When the foot valve pedal is pressed, air forces the drilling spindle down. When the valve pedal is released, the air pressure automatically raises the spindle.

Oil Hydraulic Cylinders

Lindberg Engineering Co., 2444 W. Hubbard St., Chicago 12, Ill.

Hydraulic piping can be simplified because ports on this unit can be positioned to meet particular applications. Caps, flanges, cylinder tubes, piston rods, and C-rings are made of all steel construction. Pistons are of aluminum





Conformity to your specifications is guaranteed by the unequalled accuracy of Booth dies.

Booth uniformity of quality and cutting will show you immediate time-savings in assembly of parts. Quality *plus* Experience is the only sure formula for complete satisfaction.

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APPLICATION CHART AND SAMPLE KIT... *contains swatches of S.A.E. felt types, with specification tables. Write for it. (No sales follow-up.)*

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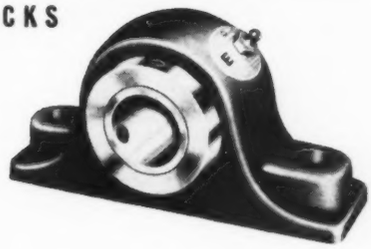
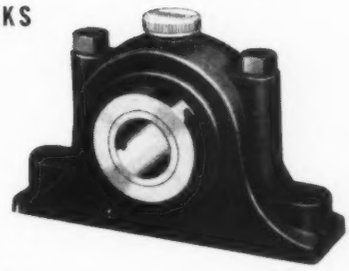
PRECISION CUT FELT PARTS

DODGE-TIMKEN TYPE "E" PILLOW BLOCKS



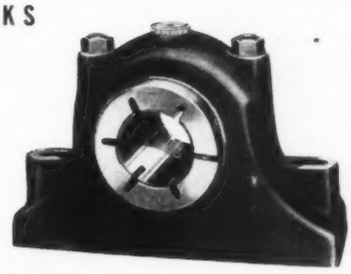
Superior performance at moderate cost. High speed capacity. Sizes 1-3/16" to 4".

DODGE-TIMKEN DOUBLE INTER-LOCK PILLOW BLOCKS



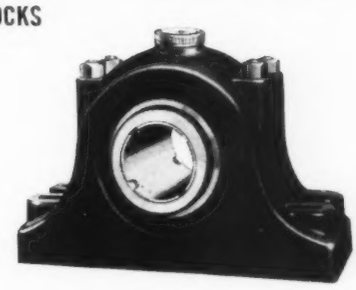
For general service. Normal radial, thrust and shock loads. 1-7/16" to 4-15/16".

DODGE-TIMKEN TYPE "C" PILLOW BLOCKS



Triple sealed against fine abrasive dust. Shaft sizes are 1-3/16" to 4-15/16".

DODGE-TIMKEN SPECIAL DUTY BALL AND SOCKET PILLOW BLOCKS



Rugged, heavy duty, high speeds. Made in shaft sizes from 1-7/16" to 8".

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On anti-friction bearings, these two names are assurance of dependability and performance which enable you to cut costs and increase production. Dodge mounts, seals and houses the precision bearing assemblies and delivers them fully assembled, adjusted and lubricated—ready to lock on the shaft. Parts required for mounting these bearings are manufactured complete in the Dodge factory—from foundry through many precision operations on the latest machine tool equipment. The bearings pictured are from the famous Dodge 30,000 hour line, covering a broad range of industrial bearing requirements, promptly available from distributors' stocks.

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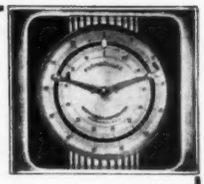
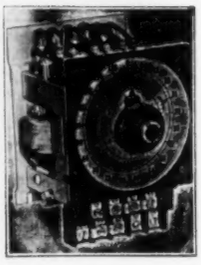
EAGLE TIMERS for Controlling Industrial Processes

REPEAT CYCLE
Use where ON-OFF operation is continuously repeated. The ON time and OFF time are each adjustable on the dial. (FLEXOPULSE)





MICROMETER DIAL

Provides exceptional timing accuracy where a circuit is to close or open with a time delay. Timing adjustable over wide range. (MICROFLEX TIMER)

COUNTER

Use for limiting a process to an exact number of operations. The counter contact opens after 1 to 400 electrical impulses as selected on dial. Automatic spring reset.

(MICROFLEX COUNTER)

MULTIPLE CIRCUIT —ADJUSTABLE

Use where several circuits are to close in a predetermined sequence. Time of closing and opening each circuit is adjustable. (MULTIFLEX TIMER)

To reduce costs and improve quality of your products by automatic TIME-COUNT control . .

★ Write for catalogue Bul. 291
★ Send details of your control problems to Eagle for recommendations.
★ Consult Eagle representatives in principal cities.

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. . . to help you simplify product improvement and development

RULAND offers an engineering service—from the design to the production of the finished product—on all types of screw machine parts, simple or complex.

This service covers parts and assemblies not only of steel, alloys, brass, aluminum and copper but also of silver, hard rubber and plastics.

RULAND "Know how", backed by modern facilities and experienced personnel is at your service.

Ask for cost estimates on your requirements.

Ruland MANUFACTURING COMPANY,
Contract Manufacturers of Carefully Made Screw Machine Products.
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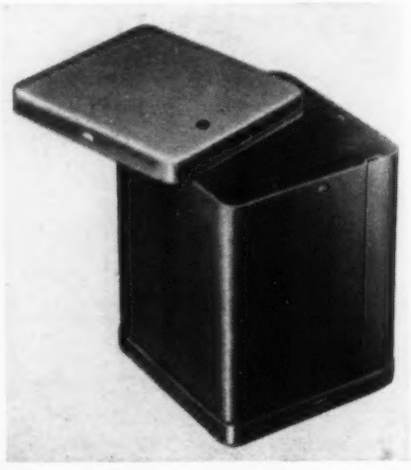
alloy with step seal piston rings. Neoprene O-rings are used instead of conventional gaskets. Sealing action is automatic; the higher the pressure the tighter the seal. Tie rods are unnecessary with this C-ring construction and installation space is saved. These cylinders will operate at 1,500 lb. per sq. in. working pressure.

Transformer Cans

Olympic Tool & Mfg. Co. Inc., 39 Chamber St., New York 7, N. Y.

The "Snap-Lock" idea has been applied to all Olympic standard aluminum and steel transformer cans. This improvement results in a saving in time

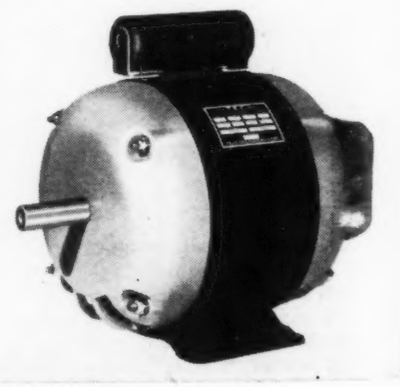


for assembly, since it eliminates the necessity of using screws. The lock seam has been moved from the center of the can to the corner, giving more inside space.

Fractional Horsepower Motors

Triad Engineering Corp., 2414 S. La Salle St., Chicago 16, Ill.

This fractional horsepower motor is suitable for heavy-duty applications such as, deepfreeze units, stokers and water pumps. The capacitor start, ball



bearing motor is rated at ¼ h.p., and runs at 1,725 rev. per min. on 60 cycle, 115 volt, single phase. It is a high starting torque, continuous duty motor.